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TECHNOLOGICAL AND ECONOMIC ASSESSMENT OF TELEMEDICINE:

AN EXAMPLE OF DOD MEDNET IN REGION THREE

by

Kirk Lorne Buker

September 1997

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The Department of Defense (DoD) has numerous initiatives underway to improve the health care delivery system within the military. Telemedicine is one of these initiatives that combine images, videos, sounds, and text to enhance the health care providers' ability to diagnosis and treat patients. The Secretary of the Army in October 1994 established, "*The Center for Total Access*" as a laboratory for healthcare re-engineering in the military. This thesis is provided as a resource guide to inform those who may become involved with this complex and chaotic field of telemedicine by providing a review of state-of-the-art technology that can support delivery of telemedicine, and by proposing a cost benefit framework for telemedicine configuration design. The material for this thesis was primarily researched utilizing Internet web browsing technologies. A review of the Tri-Service Infrastructure Management Program Office (TIMPO) project (MEDNET) is outlined as working example of a large regional telemedicine / telehealth system which was found to be the most revealing in the study of telemedicine.

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AN EXAMPLE OF DOD MEDNET IN REGION THREE

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ABSTRACT

The Department of Defense (DoD) has numerous initiatives underway to improve the health care delivery system within the military. Telemedicine is one of these initiatives that combine images, videos, sounds, and text to enhance the health care providers' ability to diagnosis and treat patients. The Secretary of the Army in October 1994 established, "*The Center for Total Access*" as a laboratory for healthcare re-engineering in the military. This thesis is provided as a resource guide to inform those who may become involved with this complex and chaotic field of telemedicine by providing a review of state-of-the-art technology that can support delivery of telemedicine, and by proposing a cost benefit framework for telemedicine configuration design. The material for this thesis was primarily researched utilizing Internet web browsing technologies. A review of the Tri-Service Infrastructure Management Program Office (TIMPO) project (MEDNET) is outlined as working example of a large regional telemedicine / telehealth system which was found to be the most revealing in the study of telemedicine.

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I. INTRODUCTION

A. BACKGROUND

The current media blitz on telemedicine makes it appear as the greatest new use of telecommunication technology of the 90's. The truth is, telemedicine has been in use in some form or another for over thirty years. The National Aeronautics and Space Administration (NASA) played and important part in the early development of telemedicine [Ref. 3]. NASA's efforts in telemedicine began in the early 1960's when humans began flying in space.

Physiological parameters were sent from both the spacecraft and space suits during missions. NASA provided much of the technology and funding for early telemedicine demonstrations [Ref. 4]. What is new about telemedicine is how the federal government and the insurance industry are actively mandating who and how patients will benefit from telemedicine technologies.

The United States spends approximately 14% of Gross National Product (GNP), approaching $1 trillion annually on healthcare, yet the country lags behind many of the other developed nations in overall population health statistics such as longevity and infant mortality rate. The healthcare industry in the United States is undergoing a dramatic change as healthcare systems reorganize and transform themselves to balance cost, quality, outcomes, and access. The manifestations of this change include the move to capitation and managed care,

shifting power structures, strategic alliances, and the threat of increased government control. [Ref. 8]

The United States industrial base has succeeded in developing the required technology to allow the health industry to adapt to the never-ending need to optimize the use of the shrinking healthcare dollars. Arthur D. Little International Consulting Organization concluded in a 1992 study that telecommunications and information technology can reduce annual healthcare expenditures in America by more than thirty six billion dollars through four of the following applications [Ref. 1]

- Some form of an electronic health record - approximate savings of $30 billion.
- Paperless submission and processing of healthcare claims - approximate savings of $6 billion.
- Paperless submission and processing of logistics request - approximate savings of $600 million.
- Remote medical consultations and professional training approximate savings of $200 million.

The telemedicine industry has been researched, studied and then has been developing the needed technology that will allow the healthcare industry to reap the billions of dollars of savings that has been proposed. It is now up to the federal government and the insurance industry to take telemedicine to the next level, which will allow the healthcare industry to truly realize the savings.

The Department of Defense, (DoD) for Health Affairs has taken the lead by establishing a DoD telemedicine test bed on 1 September 1994 to manage communication technology with military medical applications. Its specific

purpose is to re-engineer the delivery of military health service by integration of telemedicine into the Military Health Services System (MHSS) infrastructure.

The Army Surgeon General was appointed on 7 September 1994 as the DoD Executive Agent for telemedicine activities and directed the Army's Assistant Surgeon General for Research and Development to develop a management plan to guide the telemedicine project.

B. OBJECTIVE OF THE THESIS

The goal of this thesis is to provide the reader with a desktop reference on the telemedicine industry with particular emphasis on telemedicine technologies and on cost benefit issues. This thesis will outline the very first uses of telemedicine, a description of telemedicine terms in appendix form, transmission modalities, and an overview of the cost associated with telemedicine. Reviewed within this thesis are issues believed to have slowed the wide spread use of telemedicine and then outline the Southeast Medical Network Implementation Plan, (MEDNET) - DoD's answer to telemedicine.

Although telemedicine industry is used as a general descriptor, the intentions were to include DoD as part of this industry as much any civilian organization. What has worked or will work in the civilian medical industry, (for most applications) should work equally well in the DoD medical community.

The obvious focus, when possible will be on MHSS but the thesis will be helpful to anyone in the civilian sector or a member of the DoD.

C. SCOPE OF THE THESIS

The scope of this thesis will include literature review of the technological evolution of telemedicine, a literature review of DoD telemedicine projects with a specific look at MEDNET and appendices for easy reference on telemedicine terminology and the equipment industry.

This thesis will not be a step by step guide on equipment installation or setup. It could be served however as a guide in the understanding of what telemedicine is from the point of view of current technology and of cost benefit analysis.

D. METHODOLOGY

The methodology employed in thesis research includes literature reviews, consultation with the Center for Total Access (CTA), and Naval Medical Information Management Center (NMIMC). The literature reviews consists of:

- LEXUS database search of telemedicine studies, projects, and other information relating to this industry.
- A search of the Internet using various search engines, (Locus, Yahoo, and Excite) searching on the key words of, "telemedicine technology."
- A MEDLINE index search of telemedicine as a key word through the National Library of Medicine.
- A review of the MEDNET project conducted by Center for Total Access, Dwight David Eisenhower Army Medical Center (DDEAMC).

This thesis also benefits from consultation with experts at the following meetings:

- Attendance at the 1997 Annual Health Information and Management Systems Society (HIMSS) conference.

- Naval Medical Information Management Center (NMIMC) telemedicine project officers.
- Center for Total Access (CTA) MEDNET project members.

E. ORGANIZATION OF THE THESIS

This thesis is composed of six chapters. Chapter I furnishes the introduction, objectives, scope, and methodology practiced to research the telemedicine industry. Chapter II provides a brief overview of telemedicine from an evolution perspective. Chapter III outlines the technological infrastructure needed for telemedicine communications. Chapter IV discusses the cost and benefit considerations associated with a telemedicine facility. Chapter V reviews the Tri-Service Infrastructure Management Program Office (TIMPO) project Southeast Medical Network (MEDNET), a successfully working example of a large-scale regional telemedical system. MEDNET was found to be the largest most comprehensive active working telemedicine system. Chapter VI covers conclusions, lessons learned, summary, and recommendations for future research derived from conducting this thesis study.

II. A BRIEF REVIEW OF TELEMEDICINE

A. TELEMEDICINE / HEALTH EVOLUTION

Telemedicine can be best described as the use of electronic signals to transfer medical data (i.e., high-resolution photographs, radiological images, sounds, patient's medical records, and video conferencing) from one site to another which has been in use in some form or another for over thirty years.

The Department of Defense defines telemedicine as: *The extension of health services over time and distance using computer and telecommunication technologies to expand access, improve quality and control cost.*

- The Bureau of Medicine and Surgery defines telemedicine as:
  An umbrella term, which encompasses various technologies
  Applicable to the delivery of healthcare including but not limited to:

- Teleconsultation: A video consultation between a physician and a health management team to facilitate diagnosis or general health maintenance.

- Teletraining: Video technologies used to provide training to the medical community, which could include seminars, conferences, and professional, training requirements. (NMIMC 1995)

- Teleradiology: The digitized display of radiographic images for diagnosis and consultation.

The National Aeronautics and Space Administration (NASA) efforts in telemedicine began in the early 1960's when humans began flying in space (Bashshur and Lovett, 1977). This was one of the first real uses of what we

define today as telemedicine. By doing this, NASA has earned the title as one of the true pioneers of this medical technology.

NASA's research has led other research studies to try to solve the problem of how to provide care to patients in remote location. One of the more written about communities to receive medical care via telemedical services is the Papago Indians that live on a remote reservation in the state of Arizona.

The study earned the acronym (STARPAHC), which stood for, "The Space Technology Applied to Rural Papago Advanced Healthcare." This project had three stakeholders involved with its successful implementation, Lockheed, (now Lockheed-Martin), NASA, and U.S. Public Health Service. The project carried out research in the use of audio and audiovisual telecommunications to provide medical service to astronauts in space, while providing general medical service to communities on the reservation.

The remoteness of the communities provided a test bed to simulate the application of remote telemedicine. When the patients were able to later travel to a physician for a follow up on their earlier diagnosis it was found that, the video diagnosis's were 98 percent as accurate face-to-face consultations. The other two percent erred on the diagnosis for the sake of patient safety (Murphy, 1974).

Many of these "first generation" telemedicine projects never made it beyond the 1970's. If it had not been for the manned spaced vehicle program that NASA conducted during the 1980's (Preston, 1983) telemedicine would of been lost for a decade.

Now in the 1990's, with the media blitz stemming from President Clinton's task force on health reform, telemedicine, and telehealth is looked upon as America's cure to its aligning healthcare system. The main reason many of the early studies were abandoned, was the inability to show how telemedicine can save cost, improve quality, and accessibility of care. Telemedicine is now viewed as the main way to save cost, improve quality, and accessibility of care as evident by the twenty one telemedicine-related bills the 104th Congress have introduced; two which have been passed into law.

B. TELEMEDICINE BARRIERS

What the early telemedicine studies showed were how particularly useful it is in rural and remote areas that struggle to gain access to timely, quality specialty medical care. Now, the transfer of medical data has never seen such a bright future. The healthcare provider has the option of using the Internet, Satellites, and or Telephone lines while still utilizing video conferencing equipment that has proven to the most useful.

Health providers employing telemedicine is growing in a number of medical specialties, including, but not limited to: Hematology, Oncology, Radiology, Surgery, Cardiology, Psychiatry, and Home healthcare. A trend nationally is the use of telemedicine in correctional facilities which save time and money for inmate transportation also the safety for healthcare personnel and the public is increased.

Telemedicine has become a high tech solution to the universal problem of access to healthcare. Because of telemedicine, geographical isolation need no longer be an insurmountable obstacle to the basic needs of timely and quality medical care.

The latest use of telemedicine has been a two-way live audio-visual video exchange at Georgia Baptist Medical Center in Atlanta. Healthcare providers from the, United States, United Kingdom, Belgium, Italy, Canada, China, Germany, and Japan had an opportunity to exchange medical information during a live interactive laparoscopic surgery for colon and gastric cancer. In Paris, during the same session, urologists performed a pelvic node dissection for prostate cancer. Both procedures had panelists available for questions during the surgeries.

C. LIABILITY POTENTIAL OF TELEMEDICINE

With the technology available, cost at a more reasonable level, what is holding the technology back? It all points to one thing; liability of telemedicine is different from face-to-face care. The Association of Telemedicine Services Providers (ATSP) represents organizations that provide telemedicine services, and works to advance the field of telemedicine through advocacy efforts, emphasizing practical standards and process, and information services. ATSP is hosting a conference in Portland, Oregon October 1997 in collaboration with Physicians Insurers Association of America to help identify and address factors that make the liability potential of telemedicine different from face-to-face care.

Along with the liability issue of telemedicine, who is going to pay for the various telemedicine / health services is as equally important.

D. TELEMEDICINE REIMBURSEMENT

The Balance Budget Act of 1977 (H.R. 2015) includes section 5156 that provides for Medicare reimbursement of telehealth. In general, the section allows reimbursement for Medicare beneficiaries who receive healthcare services via telecommunication systems and who live in a rural area or county not adjacent to a metropolitan statistical area. This provision must start no later than July 1, 1998 and requires the Secretary of Health and Human Services (HHS) to establish a methodology for determining the amount of payment.

The section stipulates that the payment is shared between the referring providers and the consulting provider, and should not be higher than the current fee for services they provide. The reimbursement does not cover the cost for the line charges or facility fees. HHS must summit to congress no later than January 1, 1998, the details how telemedicine / telehealth services are expanding access to healthcare through the clinical efficiency, cost-effectiveness; quality of services delivered, and the reasonable cost of telecommunication charges incurred in practicing telemedicine in rural and underserved areas.

The Federal Communication Commission, (FCC) advisory committee on telecommunications and healthcare stated in its October 15, 1996 report that, "a lack of standards and the results of incompatibility of telemedicine / health systems is an obstacle to the development of this industry." In July 1997, the

FCC and the non-profit group Healthcare Open Systems and Trials, (Host) co-sponsored a forum to address the barriers to telemedicine / health expansion.

These and other forums are needed to help further the goals set by congress of increasing Americans access to healthcare through the promotion of the telemedical services.

E. VIEW FROM THE FUTURE INFORMATION HIGHWAY

Given progress in overcoming the barriers just discussed, and the national interest in universal healthcare now aroused, it seems clear that there will be a steady growth of applications in telemedicine. Simply the debate over healthcare reform promotes attention to needed improvements in the delivery of services, and it seems a truism of our age that technology is called upon as an agent of change. Some of the enhancements this author feels we may expect to see are:

- An improvement in the overall administration of healthcare in the United States.
- Improved access for physicians (ease, speed, and accuracy) to information vital to diagnosis and treatment.
- Easier access for physicians to consultative services through enhanced telecommunication links with major medical centers, including remote analysis of diagnostic data.
- Third party reimbursement for medical cases will extend to telemedical services.
- Expansion of information services into the home will improve opportunities for emergency communications, remote monitoring of vital signs, as well as public education in health matters.
- Training of healthcare professionals will be more widely available due to advances in distance and on-site instructional media.

- There will be improved diffusion of medical services in traditionally underserved areas by networking rural clinics with each other and with major medical facilities, as well as by improved links for emergency and consultant services directly to homes.

- Public health services can move their intelligence and resources closer to their client populations through administrative decentralization.

- Medical information systems will enhance the efficiency of transferring knowledge from research into training or practice by improving the methods of information gathering, storage, and retrieval.

- Improved methods for gathering, assembling, and interpreting data from the field will enhance the analytical power and hence, medical planning, policy-making, and evaluation of programs.

- Many of the most successful applications of telemedicine will be evaluated at the outset for their commercialization potential.

F. CONSIDERATIONS FOR THE FUTURE OF TELEMEDICINE

Computer Motion demonstrated one of it devices, (telesurgical robotic system) during an April 10th, 1996 grand opening of Yale University School of Medicine Endo-Laparoscopic Center. The company is working with Dr. James C. Rosser, Director of the Center in support of his research and education programs in telesurgery and robotically assisted laparoscopy. The introduction of AESOP (pronounced eesop) at the training center is viewed by Yale as a movement towards integrating robotics into advanced minimally invasive procedures by providing perfectly steady and controlled video images.

Dr. Rosser stated during the grand opening that, "Using the AESOP technology in telementoring applications significantly changes the ability of the remote surgeon to participate in the procedure."

Inviting, as the above prospects seem for the future of healthcare, they will not be realized without major emphasis in national policy and attitude regarding telemedicine. One attitude that we must face up to is building a new national telecommunications infrastructure, it is critical that this be done with an eye toward benefits for the whole range of American citizens.

If we have a network only accessible by the "information haves," we will only increase the socioeconomic of some and the increasingly political gap between our society classes. Like public education or transportation, and the public switched network, the information highway must be accessible to all citizens who wish to partake of its services.

In a large-scale view, this is not only a positive economic policy but also one that can make available new tools for trying to solve our nation's mounting problems in education and healthcare. It is hoped that this subliminal image into an expanded vision of telemedicine is an argument in that direction.

Finally, our society should not follow the belief that, for improvements in telemedicine to take place our government or big business will need to be involved. Areas for technology commercialization abound in the field of telemedicine, from developing specialized hardware or software for medical applications, to the installation that will likely come from small businesses and technology-based entrepreneurial communities.

There will be no future view of healthcare improvements from the information highway without a full range involvement. It will need more than government and big business. Critical is the grass roots level are the physicians,

nurses, administrators, and the inventors that will create and use the affordable telemedicine equipment that will lead us into the new millennium.

III. TECHNOLOGICAL INFRASTRUCTURE FOR INFORMATION TELEMEDICINE

A. TELEMEDICINE EQUIPMENT

An 1974 study by SCI Systems of Houston, Texas had shown that video requirements for remote medical diagnosis that are 98% accurate requires no more than [Ref. 17]:

- Resolution no less than 200 lines per frame
- A frame rate no less than 10 frames per second.

At this level of resolution, the telemedical industry would consider the system to be a low-end type. A high-end system would have at least 30 frames per second and at least 500 lines per frame; NTSC standard covered in chapter two.

The telemedical industry classifies the systems into four general categories: [Ref. 14]

1. Group Videoconferencing Systems
2. Desktop Systems
3. Compact Videoconferencing Systems
4. Network Systems

Group Videoconferencing Systems are classified as meeting tools. They allow distant multiple users simultaneously.

Desktop Systems were created with a face-to-face type of consultation situations in mind. These systems support a lower bandwidth, which lowers cost but decreases its interactiveness.

Compact Videoconferencing Systems are made with the mobile user in mind. Its main function allows laptop mobile users to connect to the home office for a videoconference while on the road.

Network Systems allow pre-programmed video broadcasts to be played over a corporation LAN or WAN. Most networks that have ISDN or greater level of service (covered in chapter two) can play real time videos that are of a 30 frames per second level of quality.

The basic components common to all 2:2 telemedical systems are: the camera, the microphone, the speakers and monitor, the multiplexer (MUX), Channel Service Unit / Data Service Unit (CSU/DSU) converter, the Coder/Decoder module (CODEC), and the user interface or keypad.

High-quality color composite cameras are part of most CODEC kits that can be purchased from a vendor. To lessen incompatibility problems, it is recommended that the CODEC, camera, and microphone are purchased from the same vendor. These items can be found all together as a complete kit.

Camera:

High quality NTSC video cameras as low as $180 are available from a multitude of vendors. The high quality cameras allow high resolution still image grabs where the lower-end ones are not.

Microphone:

In clinical settings where confidentiality is required, a combination microphone / speaker should be considered. The JABRA corporation has a microphone / speaker combination that is all included into the earpiece.

Speakers:

A large variety of speaker's combinations is available. The only requirement is a soundcard. In most application, the soundcard and speakers are sold as a packaged product.

Monitor:

Per SCI Systems Study, a resolution of no less than 200 lines per frame is easily met by most if not all lower-end monitors sold. Also in this area, there are a large array of devices to select form.

The only added feature, which may be needed in remote physician to patient applications, would be the ability to pan, tilt, and zoom the camera. Vendors have a plethora of options, which most will be more than happy to accommodate any request for bell and whistles.

The standard peripheral equipment that most sites will have access to are laser printers, color printers, facsimile machines, flat bed scanners, and a videocassette recorder. The addition of this equipment will only assist the healthcare provider; in most case are not needed. The videocassette recorder will only be needed if later viewing of consultation is required.

Peripheral Devices:

Printers, (Laser or Colored), digital still cameras, and a video cassette recorder can augment the telemedical site. Printers come in a variety of capabilities with price increase rapidly as resolution, (pixels per inch) increase. Some video cameras capture still images but are not as mobile. Digital still cameras allow pictures to be stored to a PC or printed out. Videocassette recorders enable the telemedical site to record a consultation for later review.

Medical Peripheral Input devices:

Multitudes of peripheral devices with fiber-optic transmission media are embedded into them for the visualization of the patients' interior organs is available. A listing of telemedical input devices are provided in Appendix F.

Most medical devices that have been designed for use with a CODEC will plug into the CODECs standard video jack. Most CODECs have three to four ports for these plug-in devices. Varieties of medical instruments are available depending on the specific clinical application. These devices usually have an optical grade fiber embedded into them for viewing of the patients' interior organs. This facilitates diagnosis that in the past would have had to have some form of exploratory surgery performed for such a diagnosis.

Multiplexer and CSU/DSU converter:

A multiplexer allows two or more signals to be sent over the same transmission line. This is accomplished by breaking up the information, (Images, and / or Audio) into packets or frames depending on the type of modulation technique the multiplexer uses. The multiplexer also allows the user to select a

fraction of the available bandwidth when combined with digital switching from the telephone companies. A CSU/DSU converter is required if the telemedical system uses a T1 transmission line. Some vendors combine the CSU/DSU and multiplexer into one device which facilitates testing and trouble shooting when technical problem arise.

Satellite Transmission Devices:

A Satellite type of transmission will require an uplink to the satellite from the transmitting station as well as a downlink at the receiving station. The number of transponders leased on the satellite depends on a weather a system will need multiple 2:2 capabilities; simultaneous users at several locations around the world. The industry has a variety of frequency levels that can be transmitted on each; having there own limitation that a vendor can emphasize.

Greater use of telemedicine can be directly attributed to standardization of equipment. The first generation of commercial telemedicine video equipment was based upon proprietary equipment algorithms. To ensure interoperability purchase all equipment from one vendor.

B. BANDWIDTH REQUIREMENTS

Bandwidth is the width of an electrical transmission over some type of transmission media usually express in terms of the range of frequencies it can pass. In North America, it is specifically defined at the 10-dB points about the reference frequency of 1000Hz, approximately the band 200-3300 Hz [Ref. 6]. The standard analog telephone channel allows the use of a 4-kHz of bandwidth

per signal. A voice grade signal has an effective bandwidth limit of 300 to 3400 Hz.

Traditional "analog" telecommunications involves transmission of an electrical or broadcast (electromagnetic) wave pattern that has the same qualities as an acoustic sound wave. The transmitted wave is an analog of the acoustic wave to be transduced back to its original form at the destination.

Digital signal forms are bursts of binary (combinations of a two-state like signals "0" and "1") information that can code as many characteristics of an acoustic wave as needed to reproduce it at the destination. Digital representations can be highly compressed to increase transmission capacity and speed. Another advantage of a digital network is that it is readily compatible to computer architecture which are digital.

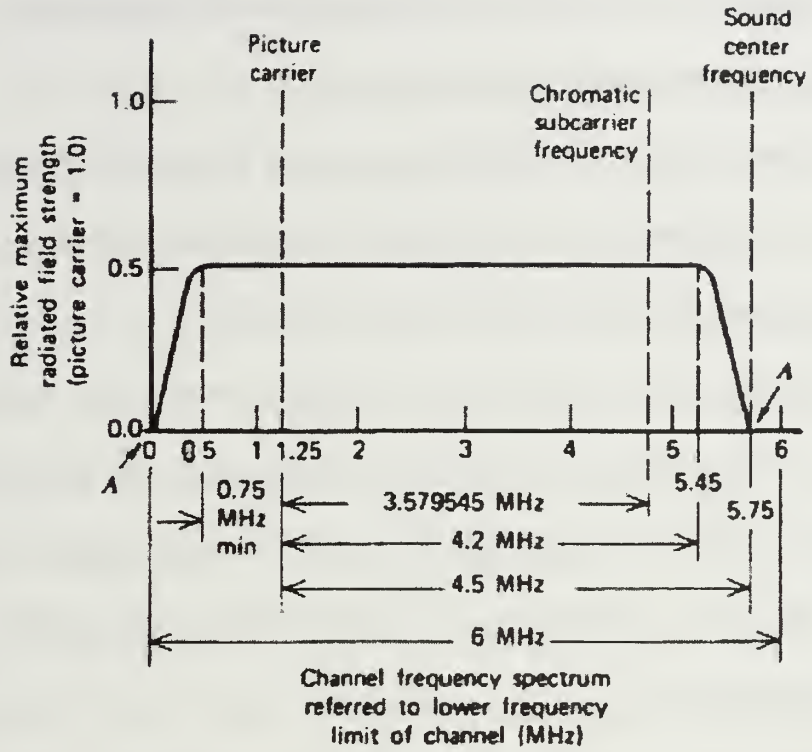


Figure 1: TV Channel Frequency Spectrum, [Ref. 6]

Since video can also be converted into digital form, this means that a single telecommunications channel can carry alphanumeric characters, voice, and video in a single coding and routing system.

Broadband typically refers to circuits that are of greater frequency range then used by voice grade circuits and often ones that carry a broadcast quality TV images. The cable TV industry is the main user of this type of transmission media when trying to reach the home user.

Full motion video requires six MHz of channel bandwidth when transmitted in North America and 7 to 8MHz to be transmitted in Europe. These

bandwidth requirements prevent interactive video from being transmitted over normal voice grade telephone channels of four kHz.

A video signal must be transmitted at the rate of approximately ninety million bits per second (Mbps) to achieve the effect of full motion real-time video. This would be equivalent to 4500 telephone lines [Ref. 14].

To get around these limitations the industry invented a device to compress videos to approximately 1/300th of it original size for transmission. Then on the receiving end, a device to decode the compression needed is so the viewer can view the video. These devices received the name CODECs (an acronym for coder / decoder).

The CODEC performs the multiplexing of the digital audio, full-motion video pictures. The early version came in a package about the size of a refrigerator. A CODEC that fits in a desktop PC can now be purchased. Most CODECs conform to the H.320 standard defined by the Telecommunications Standards Sector (TSS).

In a 1974 study funded by NASA, SCI Systems of Houston, have shown that video requirements for remote medical diagnosis that are 98% accurate requires no more than:

1) Resolution no less than 200 lines per frame.

2) A frame rate no less than 10 frames per second.

Many of the available video conferencing systems far exceed these standards for accuracy.

C. ITU VIDEO STANDARDS

The International Telecommunication Union (ITU) formerly International Consultative Committee for Telephone and Telegraph, (CCITT) interoperability standards list the overall video conferencing suite is known informally as p * 64 (and pronounced "p star 64"), and formally as standard H.320. H.320 is an "umbrella" standard. It specifies H.261 for video compression, H.221, H.230, and H.242 for communications, control, and indication, G.711, G.722, and G.728 for audio signals and several others for specialized purposes [Ref. 12].

Bandwidth can be divided up among video, voice, and data in a bewildering variety of ways. Typically, 56kbps might be allocated to voice, with 1.6kbps to signaling (control and indication signals) and the balance allocated to video.

An H.320-compatible terminal can support audio and video in one B channel using G.728 audio at 16 kb/s. For a 64 kb/s channel, this leaves 46.4 kb/s for video (after subtracting 1.6 kb/s for H.221 framing). The B channel is the basic user channel and serves any one of the following traffic types.

- PCM - based digital voice channel.
- Computer digital data, either circuit or packet switched.
- A mix of multiplex lower data rate traffic, such as vocoded (digital) low rate voice and lower data rate computer data, (Freeman,1991).

The resolution of a H.261 video image is either 352x288 (known as CIF, Common Intermediate format) or 176x144 (QCIF, Quarter Common Intermediate format.) The frame rate can be anything from 30 frames/second and down. In a

384kbps call, a video conferencing system can achieve 30 frames/second and looks comparable to a VHS videotape picture.

H.320 video/audio applications will often allocate 56kbps for audio, leaving only 68.8kbps for video.

According to the ITU document issued May 28, 1996, ITU recommend using H.323 terminals, equipment, and services for multimedia communication over Local Area Networks (LAN) but do not provide a guaranteed quality of service. H.323 terminals and equipment may carry real-time voice, data, and video, or any combination, including videoconferencing.

The LAN, over which H.323 terminals communicate, may be a single segment, ring, or it may be multiple segments with complex topologies. ITU notes that operation of H.323 terminals over the multiple LAN segments (including the Internet) may result in poor performance of videoconferencing.

H.323 is sometimes referred to as an "umbrella" specification, meaning that in the document itself there are references to other recommendations. ITU recommendations in the H.323 series include H.225.0 packet and synchronization, H.245 control, H.261 and H.263 video CODECs, G.711, G.722, G.728, G.729, and G.723 audio CODECs, and the T.120 series of multimedia communications protocols. Together, these specifications define a number of new network components (H.323 terminal, H.323 MCU, H.323 Gatekeeper and H.323 Gateway), all of which interoperate with other standards-compliant end points and networks by virtue of an H.323 Gateway.

During the development of ITU H.324 and H.323 specifications for multimedia communications, collaboration between telecommunications and computer industry leaders rose dramatically. The result is that these specifications have progressed more rapidly than their predecessors, and draw upon experiences and innovation from both industries.

The fact that H.323 promises these products and services on non-guaranteed quality of service network is an important point to consider when considering videoconferencing equipment.

D. ISO STANDARDIZATION - VIDEO STANDARDS

Standards established by the International Organization for Standardization, (ISO) include:

- MPEG1 which cover digital encoding of multimedia systems to provide VCR picture quality, similar to H.261
- MPEG2 is an extension of the MPEG1 algorithm that will provide picture quality equivalent to interlaced broadcast television.

The propose of these standards are to address three of the more critical factors affecting performance of telemedicine video equipment:

1. The rate an image is displayed on the screen, frame rate.
2. Resolution or clarity of color, contrast, and image depth.
3. How smoothly the images move across the screen.

The establishment of standards helps to prevent interoperability of equipment and lessens the ability of one company to dominate the market.

All of these standards have lead to the two sub-categories of Telemedicine:

- Telemedicine: is used to make diagnosis or to assist in surgery.
- Telehealth: is used to monitor stable patients while not under direct supervision of medical personnel.

Within each of these two categories are other subcategorizes that help to further define its specific purpose.

E. DIGITAL SUBSCRIBER LINE (DSL)

The basic acronyms for all DSL arrangements came from Bellcore, so we must blame them for the basic confusion between a line and its modems. In general, DSL signifies a modem, or a modem pair, and not a line at all. Yes, a modem pair applied to a line creates a digital subscriber line, but when a telephone company buys DSL, ADSL, or HDSL, it buys modems, apart from the lines, which they already own. Therefore, DSL is a modem, not a line. This confusion becomes quite important to avoid when we talk about prices. A "DSL" is one modem; a line requires two.

DSL itself, apart from its later siblings, is the modem used for Basic Rate ISDN. A DSL transmits duplex data, i.e. data in both directions simultaneously, at 160 kbps over copper lines up to 18,000 feet using 24-gage wire. The multiplexing and demultiplexing of this data stream into two B channels (64 kbps each) and one-D channel (16 kbps), and some overhead takes place in attached terminal equipment.

By modern standards, DSL does not press any transmission thresholds. Its standard implementation (ANSI T1.601 or ITU I.431) employs echo cancellation to separate the transmit signal from the received signal at both ends, a novelty at the time DSL first found its way into the network world.

DSL modems use twisted-pair bandwidth from zero to about 80 kHz. (Some European systems use 120 kHz of bandwidth.) They therefore preclude the simultaneous provisioning of analog POTS. However, DSL modems are being used today for so-called pair gain applications, in which DSL modems convert a single POTS line to two POTS lines, obviating the physical installation of the second line wiring. The Telephone Company just installs the analog/digital voice functions at the customer premises for both lines, and presto, two from one.

F. T1 SERVICE

In the early sixties, engineers at Bell Labs created a voice multiplexing system that first digitized a voice signal into a 64 kbps data stream (representing 8000 voltage samples a second with each sample expressed in eight bits). Then organized twenty four of them into a framed data stream, with some conventions for figuring out which 8 bit slot went where at the receiving end. The resulting frame was 193 bits long, and created an equivalent data rate of 1.544 Mbps.

The structured signal was called DS1, but it has acquired an almost colloquial synonym -- T1 -- which also describes the raw data rate, regardless of framing or intended use.

AT&T deployed DS1 in the interoffice plant starting in the late sixties (almost all of which has since been replaced by fiber), and by the mid-seventies was using DS1 in the feeder segment of the outside loop plant.

In Europe, and at CCITT (now ITU), the collection of the worlds Telephone companies modified Bell Labs original approach. Europe defined E1, as a multiplexing system for 30 voice channels running at 2.048 Mbps. In Europe E1 is the only designation, and stands for both the formatted version and the raw data rate.

Until recently, T1 and E1, circuits were implemented over copper wire by using crude transceivers with a self-clocking Alternate Mark Inversion (AMI) protocol. AMI requires repeaters every 3000 feet from the central office and every 6000 feet thereafter, and takes 1.5 MHz of bandwidth, with a signal peak at 750 kHz (U.S. systems). To a transmission purist, this is profligate and ugly, but it has worked for many years and hundreds of thousands of lines (T1 and E1) exist in the world today.

Telephone companies originally used T1/E1 circuits for transmission between offices in the core-switching network. Over time Europe tariffed T1/E1 services and offered them for private networks, connecting PBXs and T1 multiplexors together over the Wide Area Network (WAN).

Today T1/E1 circuits can be used for many other applications, such as connecting Internet routers together, bringing traffic from a cellular antenna site to a central office, or connecting multimedia servers into a central office.

An increasingly important application is in the so-called feeder plant, the section of a telephone network radiating from a central office to remote access nodes that in turn service premises over individual copper lines.

T1/E1 circuits feed Digital Loop Carrier (DLC) systems that concentrate 24 or 30 voice lines over two twisted pair lines from a central office. Thereby saving copper lines and reducing the distance between an access point and the final subscriber.

T1/E1 is not a very suitable service for connecting to individual residences. First, AMI is so demanding of bandwidth. It also corrupts cable spectrum so much, that telephone companies cannot put more than one circuit in a single 50 pair cable, and must put none in any adjacent cables. Offering such a system to residences would be equivalent to pulling new wire to most of them. Secondly, until recently no application going to the home demanded such a data rate. Thirdly, even now, as data rate requirements accelerate with the hope of movies and high speed data for everyone.

The demands are highly asymmetric, (bundles downstream to the subscriber, and very little upstream in return) and many situations will require rates above T1 or E1. In general, ADSL, VDSL, or similar types of modems will carry high-speed data rate services to the home over cable television lines.

G. HIGH DATA RATE DIGITAL SUBSCRIBER LINE (HDSL)

HDSL is simply a better way of transmitting T1 or E1 over twisted pair copper lines. It uses less bandwidth and requires no repeaters. Using more

advanced modulation techniques, HDSL transmits 1.544 Mbps or 2.048 Mbps in bandwidths ranging from 80 kHz to 240 kHz, depending upon the specific technique, rather than the greedy 1.5 MHz absorbed by AMI. HDSL provides such rates over lines up to 12,000 feet in length (24 gage) in the so-called Carrier Serving Area (CSA). IT does this by using two lines for T1 and three lines for E1, each operating at half or third speed.

Most HDSL will go into the feeder plant, which connect subscribers after a fashion, but hardly in the sense of an individual using a telephone service. Typical applications include PBX network connections, cellular antenna stations, digital-loop carrier systems, interexchange POPs, Internet servers, and private data networks. As HDSL is the most, mature of DSL technologies with rates above a megabit. It will be used for early-adopter premise applications for Internet and remote LAN access, but will likely give way to ADSL and SDSL in the near future.

H. SINGLE LINE DIGITAL SUBSCRIBER LINE (SDSL)

On its face SDSL is simply a single line version of HDSL, transmitting T1 or E1 signals over a single twisted pair, and (in most cases) operating over POTS, so a single line can support POTS and T1/E1 simultaneously.

However, SDSL has the important advantage compared to HDSL that it suits the market for individual subscriber premises, which are often equipped with only a single telephone line.

SDSL will be desired for any application needing symmetric access (such as servers and power remote LAN users), and it therefore complements ADSL (see below). It should be noted, however, that SDSL would not reach much beyond 10,000 feet, a distance over which ADSL achieves rates above six Mbps.

I. ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL)

ADSL followed on the heels of HDSL, but is really intended for the last leg into a customer's premises. As its name implies, ADSL transmits an asymmetric data stream, with much more going downstream to the subscriber and much less coming back. The reason for this has less to do with transmission technology than with the cable plant itself.

Twisted pair telephone wires are bundled together in large cables. Fifty pair to a cable is a typical configuration towards the subscriber, but cables coming out of a central office may have hundreds or even thousands of pairs bundled together. An individual line from a telephone company to a subscriber is spliced together from many cable sections as they fan out from the central office (Bellcore claims that the average U.S. subscriber line has twenty-two splices). Alexander Bell invented twisted pair wiring to minimize the interference of signals from one cable to another caused by radiation or capacitive coupling, but the process is not perfect.

The preponderance of target applications for digital subscriber services is asymmetric. Video on demand, home shopping, Internet access, remote LAN

access, multimedia access, specialized PC services all feature high data rate demands downstream, to the subscriber, but relatively low data rates demands upstream. MPEG movies with simulated VCR controls, for example, require 1.5 or 3.0 Mbps downstream, but can work just fine with no more than 64 kbps (or 16 kbps) upstream.

The IP protocols for Internet or LAN access push upstream rates higher, but a ten to one ratio of down to upstream does not compromise performance in most cases.

Therefore, ADSL has a range of downstream speeds depending on distance:

Up to 18,000 feet	1.544 Mbps (T1)
16,000 feet	2.048 Mbps (E1)
12,000 feet	6.312 Mbps (DS2)
9,000 feet	8.448 Mbps

Upstream speeds range from 16 kbps to 640 kbps. Individual products today incorporate a variety of speed arrangements, from a minimum set of 1.544/2.048 Mbps down and 16 kbps up to a maximum set of 9 Mbps down and 640 kbps up. All of these arrangements operate in a frequency band above POTS; leaving POTS service independent and undisturbed.

As ADSL transmits digitally compressed video, among other things, it includes error correction capabilities intended to reduce the effect of impulse noise on video signals. Error correction introduces about 20 milli-seconds of

delay, which is too much for LAN and IP-based data communications applications.

Therefore ADSL must know what type of signal it is passing, to know whether to apply error control or not (this problem obtains for any wire-line transmission technology, over twisted pair or coaxial cable). Furthermore, ADSL will be used for circuit switched (what we have today), packet switched (such as an IP router) and, eventually, ATM switched data.

ADSL must connect to personal computers and television set top boxes at the same time. Taken together, these application conditions create a complicated protocol and installation environment for ADSL modems, moving these modems well beyond the functions of simple data transmission and reception.

J. VERY HIGH DATA RATE DIGITAL SUBSCRIBER LINE (VDSL)

VDSL began life being named VADSL. VDSL will send data at rates higher than ADSL but over shorter lines. While no general standards exist yet for VDSL, discussion has center around the following downstream speeds:

12.96 Mbps (1/4 STS-1) 4,500 feet of wire

25.82 Mbps (1/2 STS-1) 3,000 feet of wire

51.84 Mbps (STS-1) 1,000 feet of wire

Upstream rates fall within a suggested range from 1.6 Mbps to 2.3 Mbps. The principal reason T1-E1.4 decided against "VADSL" was that VDSL would never be symmetric, while some providers and suppliers hope for fully symmetric

VDSL someday, these providers will recognize that the line length would have to be compromised.

In many ways, VDSL is simpler than ADSL. Shorter lines impose far fewer transmission constraints, so the basic transceiver technology is much less complex, although it is ten times faster. VDSL only targets ATM network architectures, obviating channelization, and packet handling requirements imposed on ADSL. VDSL admits passive network terminations, enabling more than one VDSL modem to be connected to the same line at the customer premises, in much the same way as extension telephones connect to home wiring for POTS.

However, the picture clouds under closer inspection. VDSL must still provide error correction, the most demanding of the non-transceiver functions asked of ADSL. VDSL will likely be asked to transmit conventional circuit and packet switched traffic. VDSL will operate over POTS and ISDN, with both separated from VDSL signals by passive filtering.

VDSL had been called "VASDL," "BDSL," or even "ADSL" before June, 1995, when T1-E1.4 chose "VDSL" as the official title. The European counterpart to T1-E1.4, has also adopted "VDSL," but temporarily appends a lower case "e" to indicate that, until the dust settles, the European version of VDSL may be slightly different from the U.S. version. This is the case with both HDSL and ADSL, although there is no convention for reflecting the differences in the name.

What do all of these protocols means to the Information Technology Manager? ATM and SONET will probably soon form the backbone that carries information from one telephone company switch to another. The ISDN data will be repackaged into ATM cells and then passed into SONET frames and flashed across the country and around the world. When those SONET frames arrive at the other end, after transit through a number of other switching systems, they will be unpacked into ATM cells. Those cells will be delivered to the local switch at the receiving end and repackaged into ISDN frames sent to your destination.

The same will be true if you use frame rely or SMDS. The frames of each are repackaged into ATM cells, and then into larger SONET frames; the reverse occurs at the other end.

The Navy's information technology plan for the twenty first century (IT-21) outlines the use of Asynchronous Transfer Mode, (ATM) on all service members desktops, but the vast majority only has access to the plain old telephone system (POTS) capability.

There are advantages and disadvantages of each transmission mode along with great variances in cost of transmission, which is a function of bandwidth.

IV. COST BENEFIT ANALYSIS OF TELEMEDICINE

A. INTRODUCTION

Those who initiate or review a CBA will find this chapter of value. The Flow Diagram Appendix D will also be a valued addition in any telemedical system Cost Benefit Analysis (CBA).

CBA is an economic approach that can be used to evaluate a telemedical system. CBA relates the telemedical system cost, benefits, and uncertainties of each alternative to highlight the cost effectiveness of a system or facility.

Three general principles should be incorporated in a CBA:

1. Investigate all reasonable alternatives that satisfy a given requirement.

2. Consider the value of both current and future expenditures of all alternatives.

3. Consider the discounted value of each purchase in present day cost. The life cycle cost of a system in terms of present value will assist in this consideration.

Generally, CBA can be used to assess the cost and or benefits of a past or future decision. An assessment of a past system decision can help to recoup cost by knowing the value of the current telemedical system. This can also give an economic justification when new system acquisitions are considered.

An assessment of future telemedical purchases help to ensure all alternatives are considered and the one that is chosen is the best economic decision among all of the alternatives.

CBA needs to consider various priorities among current facility goals and objectives. Avoid merely seeking the most cost effective means to satisfy one specific objective or goal. A CBA is only one input to the whole decision making process. It must be weighted against political considerations, national priorities, and other related factors. CBA is not a substitute for sound judgment based on past experiences.

No matter how much care you exercise during a CBA, to consider all possible situations is unrealistic if not just cost prohibitive. A through CBA of a small, limited system can consume many hours and be very expensive. Therefore, a CBA should not be considered if its benefits are not in line with the labor cost involved or when legislative or higher authority can exempt you from completing a CBA.

The cost benefits of an effective telemedical system can be categorized as either tangle or intangible. Tangible benefits are those for which an objective monetary estimate can be made. The most obvious example of this is the salary savings when allowing one radiologist to function as a regional radiologist covering multiple hospitals and clinics eliminates a position.

Another straightforward source could be the elimination of duplicate data entry. Every patient has large amounts of personal information that must be

gathered before consideration of treatment may begin. Savings in these areas could be passed on to other functions or systems to offset cost.

The actual savings achieved depend as much on the ability and willingness to manage staff reductions as it does on the technical characteristics of a telemedical system.

Intangible benefits are those for which an objective monetary savings can not be estimated with any degree of confidence. This does not mean that it is not real or unimportant. In fact, intangible benefits of an effective telemedical system could exceed its tangible benefits. Intangibility simply means that it is impractical to obtain a sound dollar savings figure based on mere CBA alone, as intangible benefits or costs are a subjective judgment call.

A primary intangible benefit of an effective telemedical system would be the availability of improved information for patient diagnosis and treatment. A larger view would be the availability of healthcare services to otherwise unavailable remote areas. These areas could provide a reasonable sense of security to its inhabitants that would otherwise locate elsewhere.

Another intangible benefit would be the increased availability of a physician because she or he is able to maintain their continuing education requirements via teleconferencing equipment that normally requires them to leave their practice for extended amounts of time. This will free time that is wasted going and coming from the conferences which instead could be used to improved physician patient relationships.

Despite the increase in the reported cost benefits of telemedicine there has not been a lot of empirical evidence to validate these claims. An extensive literary search has found that most studies have focused on cost that compare the perceived increase in diagnostic quality or ease of, to total hardware cost.

From an entire organization standpoint, majority of the economic decisions seems to be for specific subspecialty areas like teleradiology. In these areas, like most other telemedical economic decisions are based on the specific hardware cost and fail to capture any of the marketed revenue generating cost benefits.

Since the government has funded most of the major telemedicine programs in the U.S., the primary research question has been whether telemedicine can reduce government expenditures on healthcare. Recently the U.S. Health Care Financing Administration has funded four studies (East Carolina University, West Virginia University, Iowa and Ohio) to investigate cost justification issues and help determine whether and how healthcare providers can be paid for telemedicine consultation. The Office of Rural Health policy also funded a grant allowing a $65 payment to salaried telemedicine providers in the Bassett Healthcare System in upstate New York. The advisory board includes representatives from an insurance company and a managed care organization.

Third party reimbursement for general telemedicine consultations has not been universally enacted, although Medicare and Medicaid reimbursement for diagnostic teleradiology and telepathology are approved. Private payers in Kansas and Georgia have issued guidelines for telemedicine reimbursement.

The largest concern with providing reimbursement for general telemedicine appears to be that telemedicine will increase third party reimbursements for medical care, since telemedicine will make healthcare more readily accessible to underserved populations.

Organizations that are immune to third party reimbursement issues have readily adopted telemedicine. Examples of these markets are military health services, state health institutions, Veterans Administration, the Indian Health Service, and in the private sector, capitated managed care systems[Ref. 16].

This section reports few studies that go beyond the above mentioned cost benefit analysis, as an example: comparison of overall cost of telemedicine verus revenue derived from telemedicine system usage.

B. CBA OF TELEMEDICINE: LESSONS FROM THE FIELD

1. Telemedicine Cost Studies

a. Texas Telemedicine

Arthur D. Little, Inc. [Ref. 1] reported that the Texas Telemedicine Project in Austin, Texas, produced "at least a 14% savings" over more standard medical services. According to their model, reduction in overhead and travel time was the primary sources of savings from teleconferencing (said to approximate $131.6 million per year nationally). Over two years a total 2696 patients were treated. Six lives were reported saved. Equipment payback time was estimated at 3.5 years. In addition, Lee Memorial Hospital reported $8000 profit per quarter. Increased revenues of $37,000 were attributed to reinstituting

infant deliveries and retaining local patients. Austin Diagnostic Clinic reported a net profit of $9000 per quarter; a cost/benefit ratio of 2.25; and equipment payback in 2.2 years.

b. Texas Tech HealthNet

In 1992, Texas Tech University Health Sciences Center commissioned an independent cost analysis of telemedicine services used in its project [Ref. 9]. The accounting firm compared the costs of using telemedicine with 11 randomly selected patients to the costs that were likely to be incurred if telemedicine were not available. An average saving of $1500 per patient was reported. Majority of the savings was due to the reduced cost of treating patients locally at a rural primary care center (as opposed to an urban tertiary care center) and to the reduced need for emergency transportation.

c. Medical College of Georgia, (MCG)

This program found that 81% of patients seen over telemedicine did not require transfer to secondary or tertiary care centers. In Georgia, the cost differential between rural hospital beds and MCG beds is $800. In addition to that savings, telemedicine allows savings in transportation, increased productivity, and decreased hospitalization days from treating a patient at an earlier stage. MCG reported that if rural hospitals were to retain telemedicine patients, the increase of a single patient per day to the rural hospital census would represent a net cash flow of $150,000 per year for the hospital.

d. Baylor College of Medicine

A representative for the urban telemedicine project reported that if the base system cost were $50,000 per site, cost justification could be reached at 100 hours of use per year, [Ref. 7].

e. Eastern Montana

Telemedicine Network: Deaconess Medical Center in Billings provides about 20 consults each month in dermatology, orthopedics and psychiatry. It is estimated to save patients $200 per consultation. One consultation saved $3500 in air ambulance costs. Even with these limitations, this section will still be an invaluable tool in conducting a cost benefit analysis.

2. Continuing Education Cost Studies

a. Eastern Montana Telemedicine Project

This service from Billings provides continuing education to five eastern Montana communities. Continuing education programs are delivered to physicians, physician assistants, nurses, and other health providers. There were 103 programs provided during the first year of operation, with reported cost savings to participants to be $174,996.

These savings were calculated based on the number of participants in the programs, applying average wages lost to travel (M.D.s were estimated at $100 per hour; E.M.T.s at $8 per hour; pharmacists at $17 per hour), plus mileage, meals and lodging.

b. Texas Tech University Health Sciences Center HealthNet

HealthNet reports that continuing education through video conferencing is a revenue center for the University. HealthNet provides programs to over 90 locations. It provides 450 hours of continuing education programs to 1500 health professionals. While specific figures are unavailable, the system is reported to have surpassed cost recovery and is generating revenue.

c. Texas A&M University Health Science Center

In a trial providing 62 physicians with eight classes of continuing medical education, Texas A&M reported net savings (after subtracting the costs of using VSAT/ITV system equipment) of $16,895. The savings were attributable to travel costs avoided and time saved.

3. Administration Cost Studies

Administrative cost savings have been some of the best documented. These savings are often calculated among multi-site healthcare institutions. Managed healthcare systems report large savings for using telemedicine for administrative meetings, interviews of candidates for hiring, quality control meetings, and training, obviating travel costs and lost productivity. Revenue has been generated from re-selling bandwidth and income from selling videoconferencing-meeting services to other.

a. Baxter Healthcare Corporation

Baxter provides over 100,000 products to health providers in over 100 countries. Telemedicine services are used primarily for administrative meetings and collaborative research. Several sites cost-justified equipment by travel savings, but report the real gain from improved productivity, timely decisions and competitive advantage.

b. HBO & Company

HBO & C provide healthcare information systems and services to 3500 hospitals internationally. Over a seven-month period in 1993, HBO & C reported $290,927 saved in travel, excluding the productivity savings by avoiding 3888 employee travel hours. Human resources used videoconferencing for first interviews, recording the videotapes to show to others throughout the organization.

C. A FRAMEWORK FOR COST BENEFIT ANALYSIS

Research has already shown [Ref. 4] that there is no need for higher-end, higher-costing video conferencing equipment. Early NASA studies have showed that newer technology did improve the healthcare of remote patients, but found it near impossible to calculate operating cost of the telemedicine / telehealth network separate from the other functions operating on the networks. The obvious savings came from fewer patients being evacuated for emergency reasons and fewer specialists being flown to these remote areas.

In examining a cost benefit analysis of telemedicine, it is necessary to consider who might benefit from the increase in revenues or the avoidance of cost. These economic values could conceivably be accrue to an individual provider, a healthcare institution, an individual patient, a third party reimbursement agent, and or to society as a whole.

Potential savings can include provider time and travel, patient time, and travel, savings from reductions or substitutions in personnel needed the reduction of redundant tests, and treatment early in the course of the disease when treatment is less costly.

While telemedicine may increase the number of reimbursements, it may reduce the average amount of reimbursement. Telemedicine ultimately appears to reduce overall costs to society associated with avoidable morbidity and mortality.

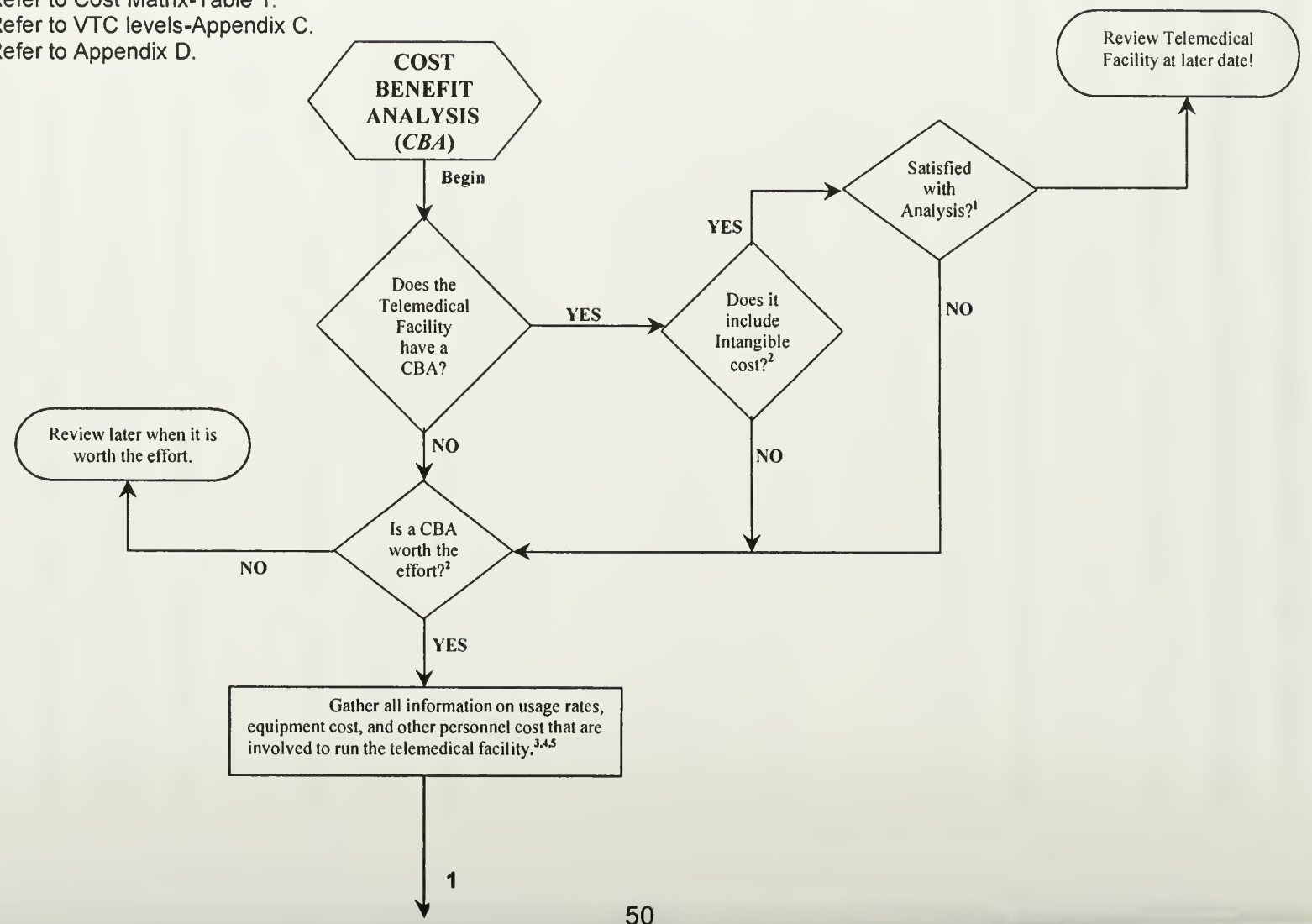
Most studies have reported on the obvious example of revenue generation that comes to physicians and clinics, those that are able to receive revenue from patient consultations. Most of these examples come from teleradiology, telepathology, and those with approved third party reimbursement, and managed care organizations.

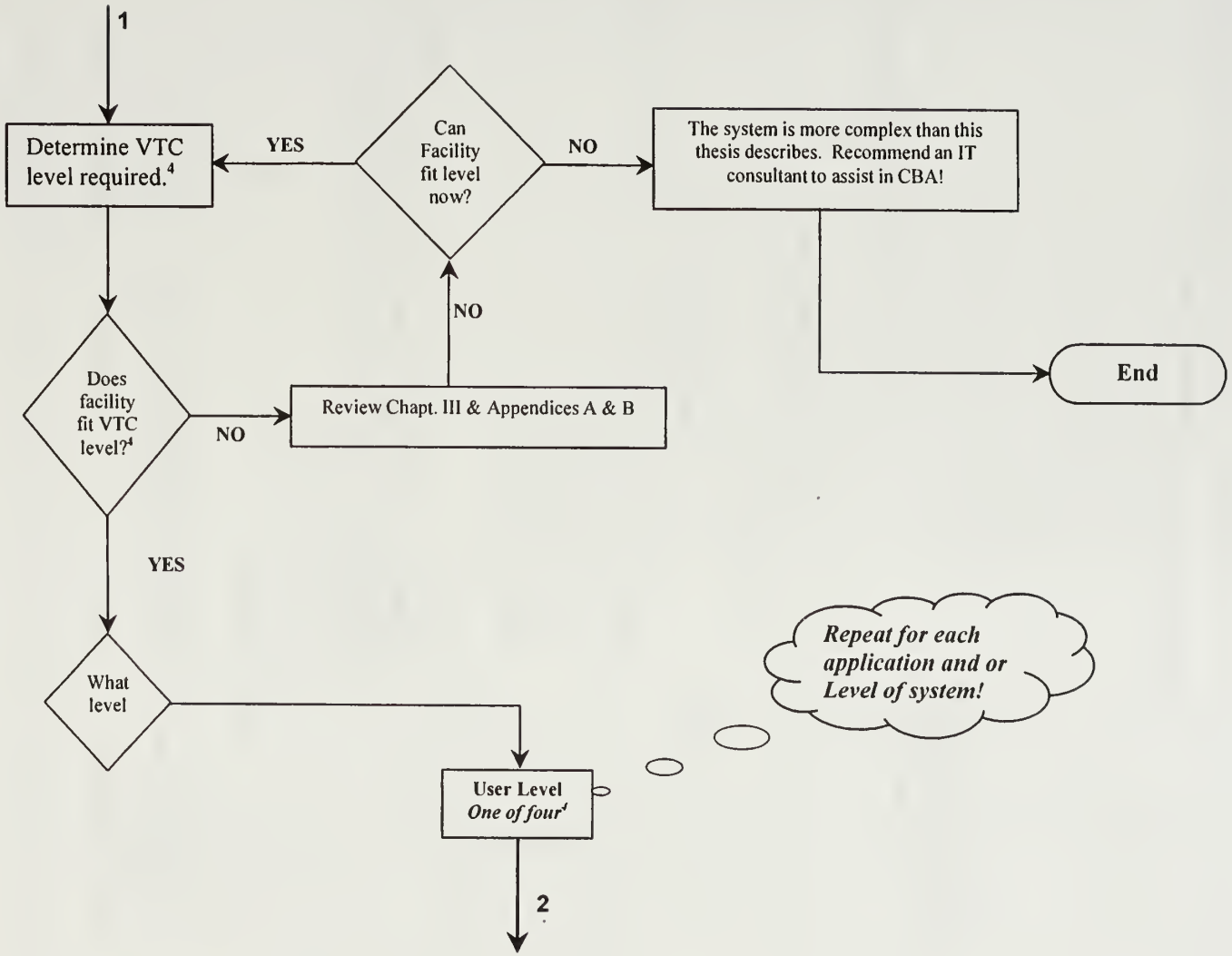
Regardless of application (consultation, education or administration) the cost of operating a telemedical system includes: installation costs, equipment cost; software cost, peripheral equipment, transmission costs, training costs for employees to use the equipment, maintenance costs.

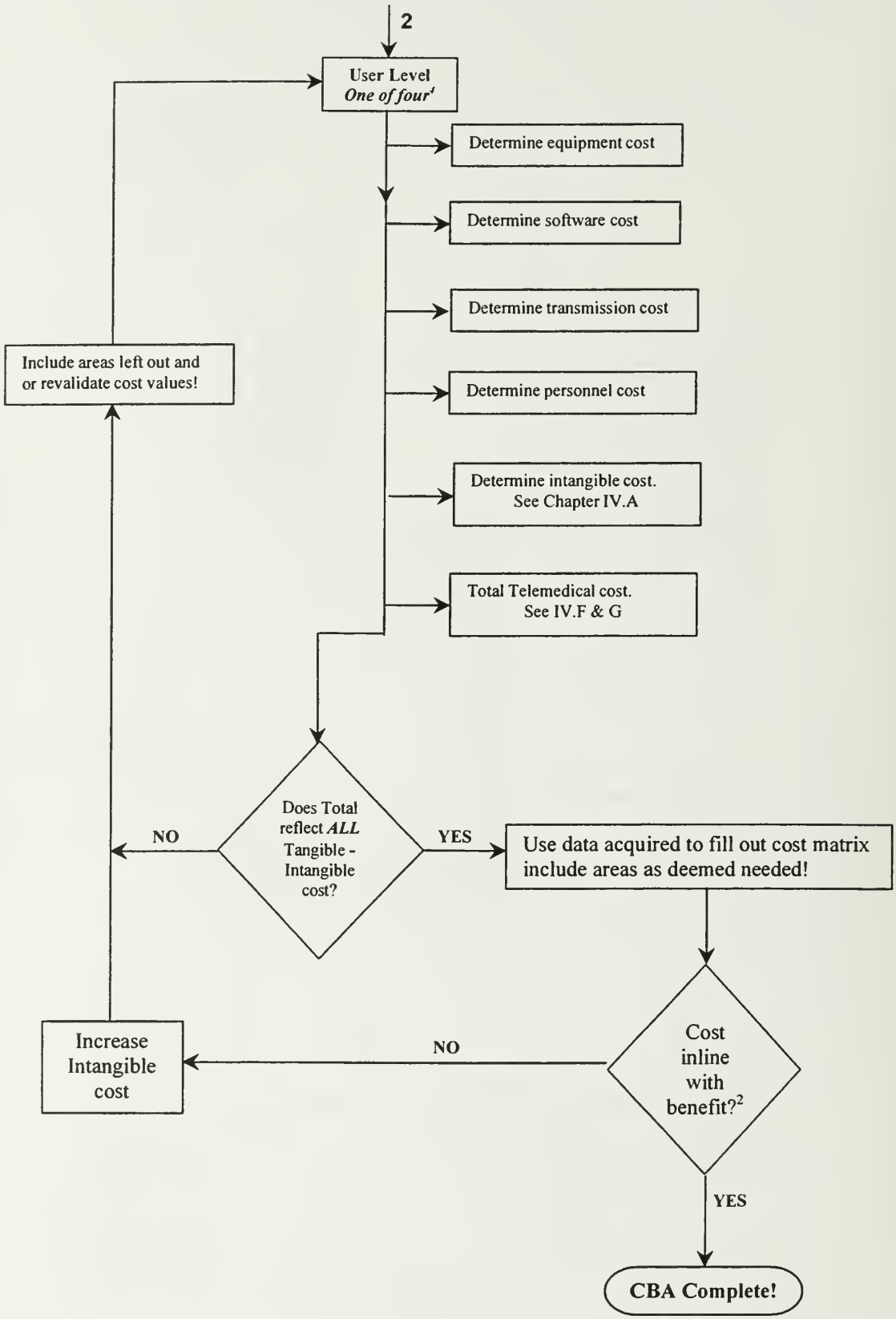
The following flow diagram proposes a framework that could be used to guide telemedicine decision-makers in identifying the most cost-effective telemedicine configuration according to their system requirements.

CBA DECISION FRAMWORK

1. Refer to Chapter IV.
2. Refer to Chapter IV-Section B.
3. Refer to Cost Matrix-Table 1.
4. Refer to VTC levels-Appendix C.
5. Refer to Appendix D.


COST BENEFIT ANALYSIS (CBA)
Begin
Does the Telemedical Facility have a CBA?
YES
Does it include Intangible cost?[2]
YES
Satisfied with Analysis?[1]
Review Telemedical Facility at later date!
NO
NO
NO
Review later when it is worth the effort.
Is a CBA worth the effort?[2]
NO
YES
Gather all information on usage rates, equipment cost, and other personnel cost that are involved to run the telemedical facility.[3,4,5]
1


1
Determine VTC level required.[4]
YES
Can Facility fit level now?
NO
The system is more complex than this thesis describes. Recommend an IT consultant to assist in CBA!
End
NO
Does facility fit VTC level?[4]
NO
Review Chapt. III & Appendices A & B
YES
What level
Repeat for each application and or Level of system!
User Level
One of four[4]
2


2
User Level
One of four[1]
Determine equipment cost
Determine software cost
Determine transmission cost
Determine personnel cost
Determine intangible cost.
See Chapter IV.A
Total Telemedical cost.
See IV.F & G
Include areas left out and
or revalidate cost values!
Does Total
reflect ALL
Tangible -
Intangible
cost?
NO
YES
Use data acquired to fill out cost matrix
include areas as deemed needed!
Increase
Intangible
cost
NO
Cost
inline
with
benefit?[2]
YES
CBA Complete!

D. A SUGGESTED COST MATRIX

Telemedicine Equipment Cost		
	Network transmission ----	
	Equipment----------	
	Software----------	
	Personnel:	
	Training----------	
	Installation ----------	
	Maintenance ---------	
	Total:	
Personnel Expense		
	Travel ----------	
	Meals ----------	
	Lodging----------	
	Lost Productivity ---------	
	Total:	
Cost Avoidance		
	Productivity gains----------	
	Personnel cost ----------	
	Interviewing cost -------	
	Consultation cost --------	
	Total:	
Savings		
	Cost per video session --	
	Minus employee cost ----	
	Plus productivity lost -----	
	Minus cost avoidance-----	
	Total Savings:	

Table 1. Telemedicine Cost Matrix

Table 1 provides an illustration of a worksheet that could be used to quantify telemedicine cost. Some specific considerations to quantify cost are discussed below:

1. NETWORK TRANSMISSION LINE COSTS

Telemedicine's network transmission line costs are often viewed as the major cost component of the system. These costs can be very high due to the needed high data rates. Moreover, the cost can range widely depending on the technological approach used. Different telemedicine technologies require different capacities or bandwidth, ranging from telephone line bandwidth required by low-tech store and forward equipment to expensive broadband infrastructure required by real time full motion television (IATV). Therefore, assessing the costs for different combinations of technologies and infrastructures can be a difficult exercise.

If a system needs full motion video type of capabilities needed will be ATM or Frame Relay level of switching technology which calls for a leased line from a network service provider. Another factor affecting the telecommunications cost and ultimately the cost of the total telemedicine system is the uneven distribution of modern telecommunications infrastructure across the country. In those areas where the information infrastructure is underdeveloped, unreliable, or non-existent, the cost of upgrading the infrastructure can be prohibitive. Yet, these areas are the most likely the ones to benefit from telemedical services. Rural areas in particular have the least access to high-quality and high-capacity telecommunications infrastructure.

2. TELEMEDICINE EQUIPMENT COST

One possible way to calculate costs would be to examine the amount of time used for a specific telemedical application. If the teleconferencing equipment is used 40% of the time for education, calculations would use 40% of the basic equipment cost. The cost of peripherals used solely for medical consultation would not be included. If certain peripherals were used solely for education, the total cost would be included (100%). For example, if a dermatology scope was purchased for use in patient consultation and not in education, do not include the cost of the scope. If remote microphones were used solely for continuing education, 100% of the cost would be included.

In an attempt to assess the cost of a telemedicine facility, be careful to address one application at a time, for example, educational videoconferencing. If the teleconferencing equipment is used for multiple purposes, the cost study of educational teleconferencing should only include the appropriate percentage of the cost of the equipment.

- Included must be any cost associated with the transmission of data from one facility to another: Leased lines, local loop fees, ISP fees etc.
- The amortized cost of your equipment needs to be considered.
- Software cost: Initial plus upgrade
- Personnel training cost are sometimes hidden in the equipment or installation cost.

3. Personnel Expenses:

- Travel includes Airfare, Taxies, Skycap tips etc.

- Meals usually include a standard rate for the specific area of traveling.

- Lodging usually also standard rate for the specific area of traveling.

- Lost productivity can be accounted for as the cost to hirer an replacement or the individuals actual salary.

4. **Cost Avoidance:**

- Productivity gain will be the revenue generated by not paying over time and / or the increased patient load that the telemedical system allows your healthcare provider to handle.

- Personnel cost are the ones not having to paid out in personnel expense that was just calculated.

- Interviewing costs are the ones saved by not paying for the potential employee to visit the location. Instead, the employer pays for a videoconference.

- Consultation costs saved are those that the employer would not have to pay the providers to perform off site consultations.

5. **Savings:**

- Take the total equipment cost and divide it by the total number of video sessions.

- From this number subtract out the employee expense to create each video session.

- To this add any productivity lost.

- The last part subtracted will be any cost that may have been avoided with the telemedical session.

- The telemedical facility will now have a reasonable cost estimate that will highlight the expenses that many researchers are trying to identify.

6. OTHER CONSIDERATIONS

The fast changing nature of the infrastructure technology itself will dramatically affect the costs of telemedicine. For example, evolving technology such as data compression is likely to significantly change the transmission times and capacity required in the future for sending diagnostic images. In the end, these advances may decrease overall costs but in the short term, it is not as clear, whether the costs will increase or decrease.

V. TELEMEDICINE IN DOD - THE CASE OF MEDNET

A. BRIEF INTRODUCTION TO MEDNET

MEDNET is a U.S. Army Medical Command project to provide a integrated data and video teleconferencing (VTC) network to support data sharing and telemedicine for the U.S. Army Medical Command (MEDCOM), it's regional Health Systems Support Activities (HASSAs), their medical treatment facilities (MTF's) and Major Subordinate Commands at a cost savings over current communications expenditures.

The Center for Total Access (CTA) has been tasked with the regional implementation of MEDNET. CTA was established by the Secretary of the Army in October 1994. The mission of the CTA is to serve as a laboratory for healthcare re-engineering in the military through the incorporation of advanced communications and informatics technologies.

As the capabilities of the CTA have become more widely known, the Office of Health Affairs has negotiated and funded several mission expansion initiatives for the organization. These include: the designation of the CTA as the site of the Theater Medical Informatics Program Test Bed ($1.1M); the implementation of the Medical Network (MEDNET) in the SE-MHSS ($3.8M); the funding of the Breast Cancer Education and Solutions Network ($1.4 M), and the designation of the CTA as the lead for the MHSS Electronic House Call convergence strategy ($1.5 M).

The CTA has attracted considerable interest from several members of Congress. Congressman Charlie Norwood (R, Ga. 10th district) is sponsoring a $5.4 million appropriation for FY 98 to support several CTA programs, including joint projects with the Medical College of Georgia for rural health delivery. The CTA enjoys an excellent relationship with academic institutions including MCG, Emory University, and Georgia Institute of Technology.

CTA works in close partnership with numerous other military organizations which include but not limited to: Health Affairs (DMIM and Clinical Business Area), TTRL, MATMO, TMIP, TIMPO, AMEDD Board, the Signal Center and School, and the Battle Command Battle Laboratory.

The centers' director, Mr. Jack Horner, leads the Medical Network-Southeast (MEDNET-SE) implementation efforts by taking the U.S. Army's plans one step further by expanding this network connectivity to approximately 23 military healthcare facilities that include the Air Force and Navy MTFs within Tri-Care Region 3 creating a Tri-Service medical network for the region "MEDNET".

B. TECHNOLOGY / BANDWIDTH OF MEDNET

The MEDNET is based on proven Integrated Digital Network Exchange (IDNX) frame-relay technology developed by the Defense Information System Agency (DISA). The IDNX provides a true network connectivity for all stations. All stations attached to the IDNX 'cloud' are connected virtually, to all other stations in the 'cloud.' What this means in the traditional sense is that there are

no inefficient point-to-point circuits. In this way, the most efficient use of bandwidth and funding is accomplished.

The major nodes (Figure 2) of the MEDNET network are located at Dwight David Eisenhower Army Medical Center (DDEAMC) at Fort Gordon, Georgia,

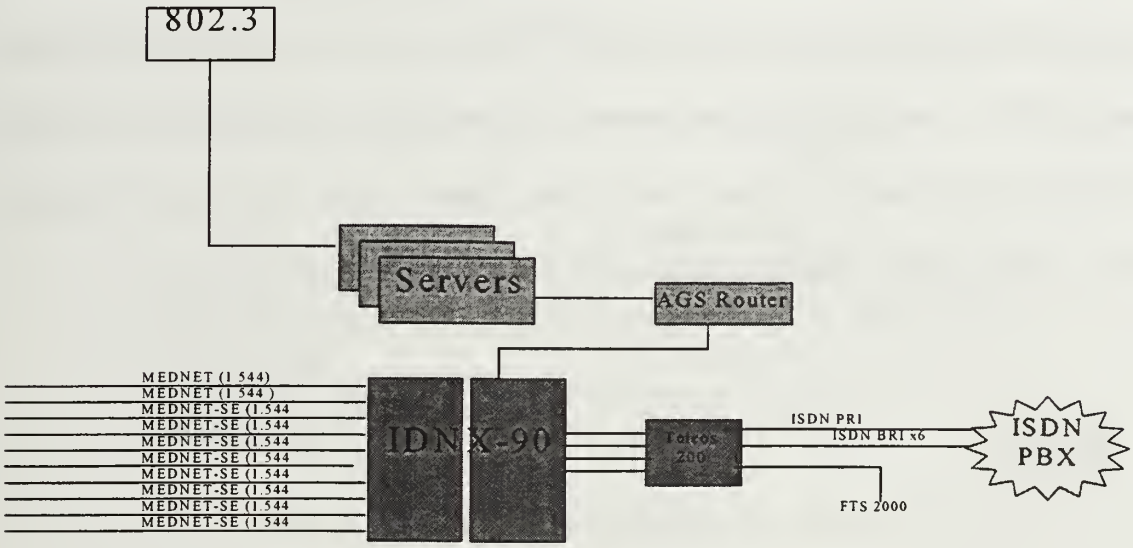


Figure 2. Major Node Configuration [Ref. 17]

Jacksonville Naval Hospital (NH), Jacksonville Naval Base (NB), and the 56th Medical group, MacDill Air Force Base (AFB). Defense Medical Human Resource System (DMHRS) is configured as the primary hub for MEDNET in the southeast region.

Each site is equipped as 'dual homed' for telecommunications. Dual homed paths are designed such that the network will continue to operate given a catastrophic failure at another site. The primary path is a T-1 service type. The

primary inter-network gateway to the MEDNET will be through the IDNX installed at Fort Gordon.

The MEDNET pathway with Brooke Army Medical Center (BAMC) and Walter Reed Army Medical Center (WRAMC) are a T-1 line with the ability to provide DS-3 services (44.744 Mb/s) as required.

The secondary (alternate) MEDNET entry path is at Jacksonville, NH and MacDill AFB. Jacksonville is connected to Fort Bragg, and MacDill is connected to Wilford Hall Medical Center, San Antonio Texas. Each facility has a standard node configuration equipment as depicted in Figure 3.

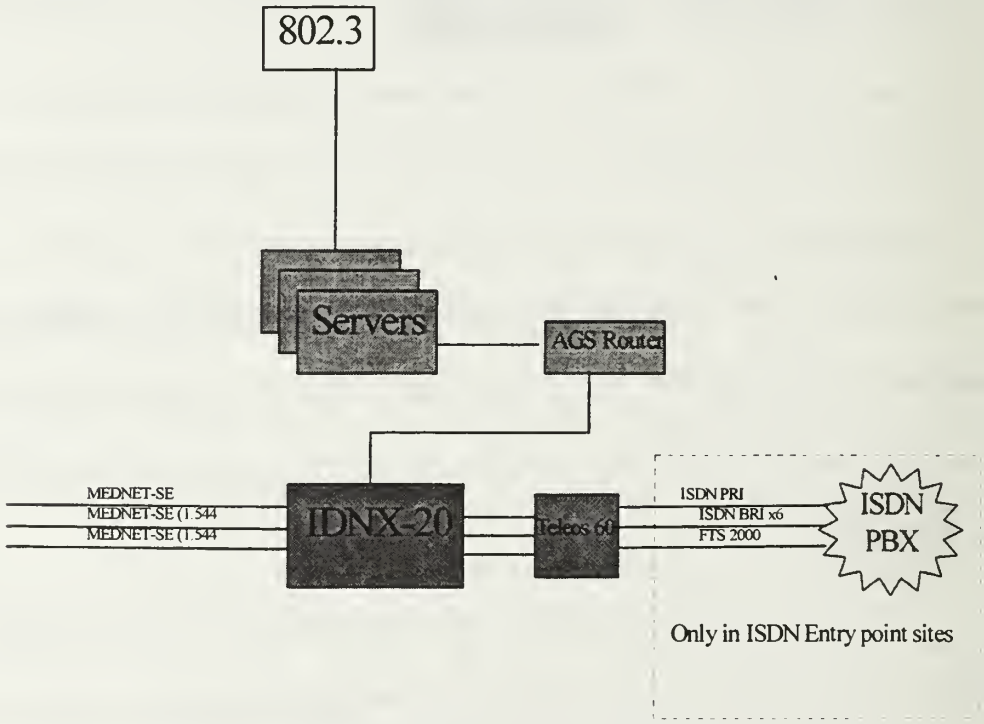


Figure 3. Standard Node Configuration, [Ref. 17]

This base configuration provides all the intended facility functionality and

will be 'dual homed. Optimally, each site will be connected to Fort Gordon (primary path), and one other site. The intent is that each site will be provided with three T-1 (1.544 Mb/s), one will be installed but not active until required.

Not all facilities will require the support of an IDNX or ATM package. These facilities will be serviced through an ISDN service multiplexer entry point at one or more of the nodes on MEDNET. The sites to be equipped for service multiplexer entry points and their service regions are as follows:

Site	Coverage Area
Fort Gordon	Eastern Georgia
Fort McPherson	Western Georgia, Eastern Alabama
Fort Jackson	South Carolina
Jacksonville NB	Northeastern Florida
MacDill AFB	Southern Florida

Table 2. Service multiplexer Entry pints, [Ref. 17]

Any other Army, Navy, or Air Force site where network services are not supported by demand but access is required, will be serviced through an ISDN entry point. The standard configuration for these facilities is reflected in Figure 4.

MEDNET is configured to support deployed forces as past of force projection operations. MacDill AFB is the primary entry point for contingency operations for US Southern Command (USSOUTHCOM) and US Central Command (USCENTCOM).

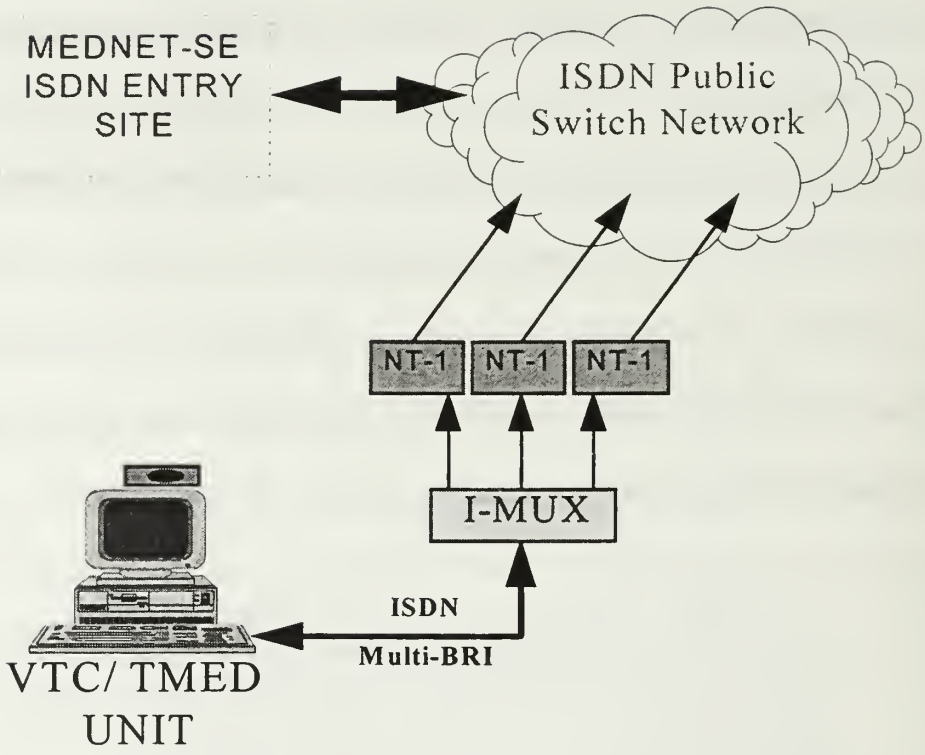


Figure 4 Remote Site ISDN Entry, [Ref. 17]

There are three ways that a deployed force can connect to MEDNET. The main connection will be through a DISN direct connection that is based on the IDNX systems. The MEDCOM has reserved four T-1 service connections supported at each site. During an operational deployment, DISA Commercial Satellite Communications Initiative (CSCI) office will be contacted to activate one or more of the T-1 service lines for connection into the DDEAMC node. This will allow full service connectivity from any deployed unit to any node connected to MEDNET.

The alternative connection is through a DISN Gateway connection. The connection to MEDNET will be via a mega-node at the Network Operation and

Deployment (NOD) Office in San Antonio, TX. This connection will provide full service connectivity from the deployed force to any MEDNET node.

Any force supported by an IDNX serviced node that can not connect to a DISN site can be connected directly to the DDEAMC node via a commercial or military satellite.

The infrastructure developed under the MEDNET initiative was based on open systems architecture. In all cases, DoD standards or best commercial practices have been employed to ensure that integration of Intranet services to approved public and private healthcare networks will be accomplished in case of an emergency.

C. COST ANALYSIS OF MEDNET

The estimated cost of MEDNET for phases 1 and 2 (Army sites), phases 3 through 5 (Air Force and Navy sites) are indicated in Table 3.

The following tables reflect the estimated cost for the major, standard nodes, and recurring costs - monthly recurring cost (MRC)/nonrecurring cost (NRC).

Phase 1	$ 644,880	
Phase 2	444,880	
Phase 3-5	1,400,980	
	Total for hardware, installation, 1st year recurring costs	$ 2,490,740
	6%Tail-end maintenance	149,444
	Total projected cost	$ 2,640,184

Table 3 Estimated Total Project Costs [Ref. 18] .

Description	Qty	Unit Cost	Total Cost
IDNX-90 1HSS, 3EXS, 115V, RCE, SHLD w/equipment	1	$ 205,877.00	$ 205,877.00
Teleos 200 Switch w/equipment	1	89,625.00	89,625.00
NRC Installation	9	1,450.00	13,050.00
MRC Communications (est)	9	800.00	7,200.00
ISDN PRI MRC (est)	1	1,200.00	1,200.00
ISDN BRI MRC	8	93.50	748.00
Total Costs (total less MRC for ISDN)			$ 315,500.00

Table 4 Estimated Cost per Major Node [Ref. 18]

Description	Qty	Unit Costs	Total Cost
IDNX-20 RCE, 24SLT, 115V, VDE, SHLD w/equipment	1	$ 66,276.00	$ 66,276.00
Teleos 60 Switch w/equipment	1	30,811.50	30,811.50
NRC Installation	3	1,450.00	4,250.00
MRC Communications	3	800.00	2,400.00
ISDN PRI MRC (ISDN Node only)	1	1,200.00	1,200.00
ISDN BRI MRC (ISDN Node only)	4	93.50	374.00
Total Costs (less MRC for ISDN for ISDN access node)		$ 103,737.50	$ 103,737.50

Table 5 Estimated Cost of a Standard Node (ISDN Service Entry Point) [Ref. 18] .

The first year of total monthly recurring costs are covered by the installation cost. Following the first year, each site will be expected to pay for the

MRC costs. A remark of CT-STS reflects the Cardiothoracic Specialized Treatment Service.

D. MEDNET INSTALLATION SCHEDULE AND FINAL REMARKS

As of June 1997, the deployment schedule was reported as in Table 7.

Installation	Projection	Remarks
Fort Gordon	COMPLETED	CT-STS, Initial Node, ISDN access node, major node installation
Fort Rucker, AL	COMPLETED	
Fort Benning, GA	COMPLETED	CT-STS
Fort Campbell, KY	COMPLETED	
Redstone Arsenal, AL	COMPLETED	
Jacksonville NB, FL	COMPLETED	ISDN Access node, major node installation
Charleston NB, SC	COMPLETED	CT-STS
Fort Jackson, SC	COMPLETED	CT-STS, ISDN Access node
Fort Stewart, GA	Aug 97	CT-STS
Miami, FL	Sep 97	Future USSOUTHCOM HQ
Fort McPherson, GA	Oct 97	CT-STS, ISDN Access node
Beaufort NB, SC	Nov 97	CT-STS
Kings Bay NB, GA	Dec 97	
Fort McClellan, AL	Jan 98	
Mayport NHC, FL	Feb 98	
Key West NHC,FL	Mar 98	
Fort Buchanan, PR	Apr 98	
Guantanamo Bay, CU	May 98	
MacDill AFB, FL	Jun 98	ISDN Access node, major node installation
Shaw AFB, SC	Jul 98	CT-STS
Moody AFB, GA	Aug 98	CT-STS
Robins AFB, GA	Sep 98	CT-STS
Patrick AFB, FL	Oct 98	
Eglin AFB, FL	Nov 98	

Table 6. Planned Installation Schedule, [Ref. 18] .

The concept of "lessons learned" is definitely a valid issue however CTA is not in a position to answer those types of questions. MEDNET is a neophyte DoD medical network. Congress has provided enough funding that has prevented

any financial short falls. The maturity of the project has also lessened the occurrence of missed objectives or equipment difficulties to speculate on the project performance thus far.

MEDNET was originally brought to CTA by the NOD (Network Operations Division) of San Antonio Texas. CTA acts as the intermediary between the NOD and the medical facilities in the region three.

On occasion NOD calls on CTA to assist with site surveys or installment of the equipment. But for the most part CTA's role in MEDNET is as an applicator. By this I mean NOD provides CTA the connection and it is CTA's job to work on putting applications across it. This continues today through the NOD/TIMPO.

The bottom line with MEDNET is: it is a young fully funded project that has the backing of the U.S. Congress who want it to succeed.

VI. CONCLUSIONS

A. SUMMARY OF RESEARCH

The medical environment faced by physicians has undergone a radical transformation over the past decade with the emergence of the information highway, telesurgery, teleconferencing, and the general advanced use of robots within the operating room.

This transformation has occurred against a backdrop of changes in the healthcare delivery system as providers have integrated themselves, managed care has strengthened, and public programs have became more sensitive to the never ending escalation of cost.

The thesis study has found that the environment is rich with diversity, yet highly chaotic. Due to the Internet, there is more information available, in more formats than ever, competing for the limited time that physicians have to keep abreast of changes in the medical world let a lone the world of information technology.

A national survey released in 1996 by Abt Associates of Cambridge, Massachusetts showed that 29 percent of the nation's rural hospital already use telemedicine or plan to have programs up and running within the years. In addition, a very promising study of 30 patients with dermatological problems conducted by the Medical College of Georgia found no difference between the diagnosis made using a telemedicine link and those made in person.

Although telemedicine systems currently are being implemented in different configurations throughout the country, they all have one thing in common. Every system depends on advanced telecommunications technologies to exchange health information and to provide health services.

While the medical community is racing to embrace telemedicine, the jury is still out -- so to speak -- on the impact of these new technologies on professional liability. A lack of professional guidelines and clear legal opinions means liability carries currently can only speculate on how telemedicine technologies will affect malpractice claims.

The root case of all the uncertainty in the insurance industry surrounding telemedicine is a lack of relevant legal precedents. The fact is many of the communications technologies being implemented are so new telemedicine malpractice cases have not made their way through the legal system.

Physician licensing represents another trouble associated with telemedicine. Theoretically, telemedicine technologies should make issues of distance inconsequential. Medical license, however stop at the state line, raising the significant question of weather physicians participating in telemedicine programs may legally practice medicine beyond their home state.

With no clear national licensure standards in place, a growing number of states are taking the issues into their own hands. California, Mississippi, Oklahoma, and Tennessee all have enacted laws or regulations which amend physician licensure standards to accommodate telemedicine concerns including

requiring out-of-state physicians to get full licensure before they can practice telemedicine on behalf of instate patient.

The greatest benefits of telemedicine are just starting to surface. The ability to perform remote medical services via telemedicine technology at correctional institutions to DoD facilities are its main asset. Telemedicine will decrease the need for face-to-face contact between the physician and patient that are geographically separated. Diagnostic procedures, clinical consultations, and continuing medical education can be conducted without negatively affecting the quality of information exchanged, or the safety of the patient treated [Ref. 4]. The inherent value that most telemedicine research studies are looking for can be gained from the ability to distribute and control medical services over vast distances while still achieving the maximal benefits that this technology can offer.

The never ending increase in the improved ability to pass larger amounts of information into the same size (Bandwidth) transmission medium will not be the prerequisite for telemedicine applications. Research has already shown that, even with low-frame-rate technologies and for portions of the total diagnostic picture to be sent, telemedicine is close to as effective as face to face diagnosis [Ref. 5]. All forms of telecommunications, not just high-frame- rate video systems, can improve distant medical care.

However, whatever the level of your telemedicine applications or scope of medical care, you must view them from the context of the larger strategic planning and systems perspective. Civilian or DoD facility alike, the design and integrated of your telemedicine system ***must*** be able to show an effective

solution to the problems faced by all healthcare delivery systems, the problems of cost, quality, and access to care. Medical organization will find that when searching for information on medicine, the latest technological advancement out weights the information on what will simply get the job done ten to one. The new technologies that use fiber optics or satellite communications surly can improve bandwidth but also your equipment cost. As stated in this thesis, the simpler, less costly alternatives will function as well for most telemedicine applications.

During these times of decreasing medical budgets the most sophisticated current technologies for telemedicine, will most likely make your telemedicine project cost prohibitive. The existing transmission modes currently in place, telephone system, computer networks, and or the television can all play important roles in telemedicine.

Properly utilized telemedicine programs will improve the ability of non-physician medical providers (Nurses, Hospital corpsmen, Army medics) to participate in healthcare delivery in remote areas. This type of medical provider is a critical resource in the DoD healthcare system, especially in remote clinics and shipboard environments, where physician support is limited or absent. Telemedicine will enhance their productiveness and expand their limited capabilities due to skills or legal requirements.

The physician and her staff are becoming increasing responsible for the total cost of the care, as the case in many military facilities. When this is the case, the economic benefits of video teleconferencing are crucial. Accounting

for personnel expenses, loss of productivity, travel cost, meals, and hotels will help to demonstrate the cost advantage of telemedicine programs.

Continuing medical education programs, in-house remote medical seminars, and administrative communications can be a very valuable source when investigating the feasibility of a telemedicine system. Consideration of these non-clinical services could be your key to a well received cost benefit analysis of a telemedical facility.

Telemedicine can also used as a screening mechanism of low-acuity cases that can be maintained within the immediate area and for complex cases, a specialists in tertiary care settings can be contacted to assist with their medical needs.

An observable benefit of telemedicine extends to remote facilities in the form of a sense of decrease isolation. Both professionally and socially, isolation is known to contribute to dissatisfaction among healthcare providers in remote areas [Ref. 10].

Assessments of the value of telemedicine should also consider other factors such as quality-of-life factors for providers and patients in these remote locations. Keep in mind, that the broader issues in determining the value of telemedicine in support of isolated facilities need to be focused on more than the traditional analysis of costs and benefits. Advantages of improved healthcare education, the influence of knowing that care is available when needed, and the increased in the quality of care are invaluable. Although these variables appear complicated to assess, they can be modeled and estimated.[Ref. 10] The area

that is the most difficult to access, will most likely be the most significant contributor to your telemedicine system.

Even with the healthcare industries numerous attempts to slow the growth of the exponentially increasing costs, the industry can not control the growth. In spite of that, there has been little formal evaluation of the role telecommunications can play in a national reform effort [Ref. 1].

Funding sources and medical schools have an influence on the direction of telemedicine technology development. Currently, for many institutions the emphasis is on the live-video aspects of medical communications. Linda Goldsmith, believes that, "Until telecommunications becomes valued by medical education (including allied health) it will be a tremendous uphill battle to integrate the full range of telemedicine technologies."

While enormous investments have been made in equipping telemedicine programs, the levels of usage for patient-care activities have been disappointingly low. Research has revealed that the majority of usage for most systems has not been for patient-care activities. Typically, a telemedicine system will be used 75% of the time for on-line education and administration, leaving the remaining 25% of the time for medical consultations. In a survey performed during 1993, it was found that there were less than 2000 patient-physician consultations in all of North America, or about five per day. Of these, half were three to five minute renal dialysis consultations done at one rural nephrology clinic in Texas. The remainder was more standard 25-35 minute consultations, comprising primarily psychiatric, dermatology, cardiology,

neurology, and oncology. The relatively small numbers are very surprising, considering the installed base of telemedicine equipment at that time amounted to many millions off dollars [Ref. 2].

Allen found in a 1994 survey that in the first six months of 1994 there were approximately ten programs in North America offering interactive teleconferencing health services, predominately in psychiatry. Out of approximately 484 consultations, nearly half were at one clinic in Nebraska.

Allen went on to review the implementation of interfaculty teleradiology, and found that there are about eleven such programs in North America, serving about 92 remote sites. In the first six months of 1994, approximately 21,000 cases were read, equating to slightly less than 50,000 per year. A normal year's caseload for a full time radiologist is about 10,000 cases. Therefore, in all of North America, the current volume of interfaculty teleradiology traffic would support only five teleradiologists [Ref. 2].

North America is not the only country viewing telemedicine as the possible mechanism to help reduce the cost of care. For example, Japan funds several telecommunications research and pilot programs. The Kyoto Prefectural University of Medicine is the only site in the world that has used high definition television (HDTV) in providing medical care. Italy is sponsoring development of a national telecommunications infrastructure. The province of Ontario, Canada, in an experiment with smart cards, has reduced unnecessary hospitalizations due to medication contradictions. The European Community's Advanced Information in medicine program is funding several demonstration programs in

Picture Archival and Communications Systems (PACS) and smart cards, and is developing standards for an electronic medical record and distributed architectures [Ref.1].

MEDNET given time will help increase DoD's knowledge level of telemedicine's true effects. Despite many initiatives underway to establish telemedicine systems throughout the world, telemedicine is still an infant technology with many shining stars yet to surface.

The opportunity now exists to fund empirical research and evaluations to isolate the cost and benefits of telemedicine so the insurance industry will be comfortable about insuring telemedicine as a valid medical treatment modality.

The need to develop strategic planning policies, technology standards, and to fund research to increase the scientific knowledge base of telemedicine has never been as important as it is now. These tools will give the medical industry the needed information to address the critical policy issues surrounding telemedicine's effect on the healthcare system.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Telemedicine has the capacity to generate unprecedented amount of information in a multitude of formats dictating the need to investigate the requirements for DoD health systems integration. The integration of telemedicine-generated multi-media information with existing automated systems such us the Composite Healthcare System (CHCS) is of critical importance in the establishment of a comprehensive electronic medical record.

CTA can provide the requirements for the strategic planning process in implementing telemedicine systems, but this still leaves the need for basic research in determining the systems integration requirements for telemedicine within the DoD TRI-CARE regions. Important issues in this area of research are the requirements for telemedicine data storage, data compression, and information retrieval and user-interface and display devices.

The need to develop a basic telemedicine system from an open architecture perspective allowing the ability to upgrade as technology improves is an important research requirement closely related to telemedical cost benefits.

Careful tracking of the licensing debate of interstate telemedicine consultations will provide a viable and useful study for DoD and the civilian sector a like. In addition, these professional groups within the various medical communities will need to work with providers of telemedicine and telecommunications technologies to enable the vertical and horizontal integration of these systems through the development of licensing standards.

Additional research on the quality care achieved with telemedicine would be useful. Although preliminary studies have indicated that the quality of care provided by telemedicine could be equal to the care received in the conventional healthcare system, additional research could possibly equate cost to the quality of care received.

The development of a telemedicine / telehealth infrastructure within DoD will provide an interactive communications network that can offer multi-media information access to the ever increasing beneficiaries. This communication

system can enable healthcare consumers with pertinent and timely information on healthcare issues. This access can also encourage our healthcare consumers to manage their own health proactively. Use in this fashion, telemedicine could help to shift the role of healthcare providers from treating sick patients in a hospital or clinic, to managing the health of people in their own home or place of work.

Research of the World-Wide-Web as a mechanism to provide access to the network of health resources through internet protocols are wide open. This mechanism could be one of the prime motivators for consumers to use the plethora of telecommunication information resources too manage their own healthcare requirements.

APPENDIX A: TRANSMISSION MODALITIES

A. INTRODUCTION

Although term "Information Super Highway" mainly reminds us all of Vice President Gore's initiative to provide greater public access to the world wide web [Ref.20], it has helped to highlight the enhancements in telecommunications over the past thirty some years. The most notable being the breakup of AT&T in 1984 this fueled new and competitive services in the industry. These advances in telecommunications have brought a renewed interest in telemedicine. Telemedicine as previously defined, can only transfer images, videos, sounds, and text types of patient data to other clinicians if both ends agree on a specific standard for the format of the data to be transferred.

The hardware and software for the most basic telemedicine systems has found its place atop most physicians' desktops. Usually, with an addition of a camera and a flat bed scanner most physicians could have what can be defined as telemedical abilities. This would give the healthcare provider the basic components that are included in most 2:2 type of systems, which are defined as each party using two-way video and two-way audio communications [Ref. 15].

Healthcare providers that are in need of higher end systems that provide greater picture resolution and faster data transfer between sites will need to concern themselves with various multiplexing techniques. Multiplexing allows

the transmission of two or more electronic signals over a telephone transmission line or by way of electromagnetic frequencies. Once these signals are placed into electromagnetic frequencies, they can be transmitted anywhere in the world via various transmission mediums.

B. TRANSMISSION MEDIA

There are four types of media used with telephone technology.

1. Unshielded Twisted-pair (UTP)
2. Coaxial cable (COAX)
3. Fiber-Optic cable
4. Radio (Microwaves)

Before Fiber-Optic cabling, long distance carriers relied on coaxial cable supplemented with microwave radio. The two were using analog radio technology to carry signals. Due to the technological advances, coaxial cable supplemented with microwave radio now use digital transmission. Fiber with digital technology has proven more economical due to its decrease in noise generation and greater information carrying capacity. Essentially, most of the telephone systems are based on fiber-optic cables carrying digital signals, [Ref. 19].

Various carriers via fiber-optic trunks connect cities and central offices within these cities. The connection between the central office and your home is the only place where you will most likely find UTP. This local loop is the

determining factor in the data rate, noise, and errors associated with the use of the telephone system. The local loop is the weakest link.

C. PUBLIC SWITCHED TELEPHONE NETWORK

Modern telecommunications networks are both managed by computers (mainly the "switches" that route messages) and offer a wide range of linkages to computer services. In some respects, modern networks are increasingly taking on the character of giant distributed computing systems, as services from the latter are available to anyone who has access to the network. As computers become ubiquitous in the network, we tend to call these networks "intelligent." In telemedicine, for example, many new network-based services represent a telecommunications link to computer capabilities. The largest and most accessible network is the public switched network that is operated mainly by telephone companies, local as well as long distance. The public network is a "common carrier," so to speak; it is available to anyone or any organization that can afford to use it.

Most of the telemedical services using the public network are traditional voice, facsimile ("fax"), or data transmissions. Because the original public network was designed with only intelligible voice transmission ("voice grade") as a requirement, its capacity is limited in both signal complexity and speed. An example of voice grade transmission would be how your voice sounds over the telephone, (a bit flat). This reflects the limited complexity voice grade lines have due to the higher and lower frequency ranges not being transmitted.

The plain old telephone system, (POTS) was engineered to carry analog voice signals. Transmission facilities designed to handle voice traffic have characteristics that make it difficult to transmit digital signals, (1's and 0's - live blood of Telemedicine). To permit the transmission of digital signals over analog voice switching facilities, it is necessary to convert the digital signal into an analog signal. This is the first point of signal deterioration due to the quantization error that occurs.

Quantization error is the result of the difference between sampled electrical current and the sinusoid electric wave that alternates between a positive one-volt or negative one-volt and carries the digital.

To convert a signal from analog to digital you will need equipment generally termed a data modem. A modem is the acronym for a **Mo**dulator and a **Dem**odulator. A modem will use one or more modulation techniques to modulate, (carry the electrical signal) and then demodulate (remove the carrier and keep the signal) the binary signal over the telephone companies twisted pair, (two copper wires) telephone lines. Amplitude modulation, (AM) is inefficient in spectrum utilization, (bandwidth) and modulating the signal. Frequency modulation, (FM) has a three to four decibel improvement over AM but is best utilized at data rates below 1200 bit per second, (bps). Pulse modulation, (PM) is the best of the three basic types of modulation for data rates over 1200bps. PM systems yield a smaller noise bandwidth and the demodulation schemes have good noise rejection capability. Most of the noise problems can be avoided when you keep your signal in a digital format. Noise in

the broadest definition, consist of any undesired signal in a communication circuit, (Freeman, 1991).

D. SWITCHING SCHEMES

There are two basic switching schemes:

1. Circuit switching
2. Packet switching

Circuit switching can be thought of as a physical mechanical switch being thrown each time a call is made. Once this call is complete, the Telephone Company switches off from that connection. The basic idea of circuit switching is exclusive use of the total circuit length of the connection for as long as the call is maintained.

Packet switching is a discrete collection of information. The information is broken up into thousands of packets. Each packet is numbered sequentially and addressed according to where it is going. The transmission mode is more fully utilized with packet switching, so when information is not being sent someone else can send information and share in the cost of the transmission line.

X.25 is the most widely accepted protocol for packet switching transmissions over the worldwide telephone system. It delivers packets in a connection-oriented service. This is in contrast to a connectionless or datagram service that most local area networks employ. A connectionless service never establishes a connection like X.25. It sends its packets with an attached sequence number. As packets arrive at the other end, they are reassembled

sequentially. If a packet is missing, the receiving protocol requests retransmission.

The POTS system is based on a person to person type of connection unicast or direct server to client connection. To receive the greatest benefits from an information system, information needs to be broadcasted one, to as many people as possible; termed "Multicast." The major problem with the POTS system is, it was not engineered with the idea to send information to multi-people during one signal broadcast.

Of course, widely used is the voice grade network for many healthcare applications including voice consultations and administration, faxing records, exchanging data in batches such as to download research reports from a medical information service or to exchange billing data over an electronic network. Although it is possible to pack more into the voice grade network, it is both technically and economically desirable to upgrade services.

Realizing the weakest link of the teleph-/9one network is the first leg of twisted pair cabling to the central offices; the Telephone Company created Integrated Services Digital Network, (ISDN) to deliver a digital rather then an analog signal. In this network, all traffic is digitally coded which allows for more use of intelligent services, as well as a substantial compression of signals so that traditional telephone lines have a much greater capacity. The advantage of this service to the customer is that several services can be operated simultaneously with a single call.

There are two ISDN services to subscribe to:

1. Basic Rate Interface (BRI)
2. Primary Rate Interface (PRI)

Basic Rate Interface delivers three separate channels; two 64kbps B channels and one 16kbps D channel. These B channels are designed to carry the data and the D channel controls the flow of the data. In twisted pair cabling control is carried within the same channel, which is called in-band signaling.

Primary Rate Interface provides 23 B channels and a signal D channel, but this D channel has 64kbps capacity. This means PRI is essentially a T1 line, (1,544Mbps capacity.)

The next level of service is Broadband ISDN; (B-ISDN) offers data rates up to 622.08 Mbps full duplex. The definition of narrowband or broadband has changed with time and technological advances. At one time, UTP was considered narrowband where now BRI or PRI type of serve is considered narrowband. Broadband typically refers to circuits greater than voice grade and often ones that carry a broadcast quality TV image (like cable TV.)

Asynchronous Transfer Mode, (ATM) is a way of transmitting information in fixed cell length of 53 bytes. Forty-eight bytes are used to carry information and five bytes are used for its header that contain the cells overhead information. These cells are handled in such a way that it creates a hybrid of circuit mode and packet mode type of transfers. ATM sacrifices flexible information size for uniformity and control.

Synchronous Optical Network (SONET) is the recommended standard fiber optic transmission protocol for ATM.

Bellcore developed switched Multimegabit Data Service, (SMDS) as a connectionless packet-mode data service. It incorporates parts of the design that went into ATM. It offers 56 kbps through 34 Mbps data rates that are dependent on telephone company offerings. The payload size of an SMDS packet is 48 bytes. A literature search seems to point to a fading away of that type of data service.

Frame relay is a major improvement in the way packet switching has been carried out under X.25. While X.25 requires at least ten steps to process the information, frame relay processes the same information in two steps. Frame relay uses the out-of-band common channel signaling technique, which are characteristics of ISDN. As a result, frame relay does not use the X.25 method of providing flow and error control between each device instead it uses higher layer protocols to do flow control and error detection.

Bandwidth limitations of voice band lines do not come from the subscriber line; they come from the filters at the edge of the core network that limit voice grade bandwidth to 3.3 kHz. Without filters, copper access lines can pass frequencies into MHz regions, albeit with substantial attenuation. Indeed, attenuation, which increases with line length and frequency, dominates the constraints on data rate over twisted pair wire. Practical limits on data rate in one direction compared to line length (of 24 gauge twisted pair) are:

DS1 (T1)	1.544 Mbps	18,000 feet
E1	2.048 Mbps	16,000 feet
DS2	6.312 Mbps	12,000 feet
E2	8.448 Mbps	9,000 feet
1/4 STS-1	12.960 Mbps	4,500 feet

1/2 STS-1	25.920 Mbps	3,000 feet
STS-1	51.840 Mbps	1,000 feet

Subscriber local-loop configurations vary tremendously around the world. In some countries 18,000 feet covers virtually every subscriber; in others, such as the United States, 18,000 feet covers less than 80% of subscribers.

However, the 20% or so remaining has lines with loading coils, which cannot be used for any DSL service (including ISDN), without removing the coils. Most telephone companies have had programs to shrink average loop length underway for a number of years, largely to stretch the capacity of existing central offices.

The typical technique involves installation of access nodes that are remote from central offices, creating so-called Distribution Areas with maximum subscriber loops of 6000 feet from the access node. T1/E1 lines (now using High data rate Digital Subscriber Line) or fiber feeds remote access nodes. In suburban communities, a distribution area connects an average of 1500 premises; in urban areas, the figure is double, about 3000 premises. Of course, the number of premises served dwindles as service data rates increase. A Fiber to the Curb system (FTTC) offering STS-1 rates may only be within reach of twenty homes in some suburban areas.

Depending on the application, an ISDN data rate of 1.5 Mbps per subscriber terminal can be offered to virtually everyone within 18,000 feet downstream that may suffice. For subscribers with shorter lines, to either a

central office or remote access node, more than one channel to more than one premises terminal can be offered.

If digital live television is needed, then at least six Mbps of bandwidth is required, which limit line distances to 4500-foot. Clearly, High Definition Television (HDTV) demanding as much as 20 Mbps, only goes over the shortest loop length. Of course, this offering of digital services over existing twisted-pair lines requires transceivers, special modems capable of dazzling data rates when one considers the age and original intentions of twisted-pair wiring technology.

Service	Name	Description	Connection	Speed
POTS (UTP)	Plain old telephone System	Analog connections through modem	Dial-up, Time Charged	Up to FCC regulated 53kbps
Swithed-56	Packet Switched Data Lines, Leased Lines or Dial-up	Switched digital service - can be multiplexed	Dedicated local loop, time charged for long distance	56kbps up to 1.544Mbps by multiplexing
ISDN	Integrated Service Data Network	Switched digital service - can be multiplexed	Dial-up service Time-Charged	2 Channels at 64kbps each up to T1 when multiplexed
T1 or DS1	Digital Service Time-Division multiplexed	Copper, fiber, or microwave high speed channels	Dedicated Monthly charge	1.544 Mbps
T3 or DS3	Digital Service Time-Division multiplexed	Copper, fiber, or microwave high speed channels	Dedicated Monthly charge	45Mbps
10 Base T	Ethernet Twisted Copper pair UTP	Most common computer interface media	User installed	10-100Mbps
Ku/C Band	Satellite channels	Analog or digital	Costly uplink; earth stations billed monthly	45Mbps per channel
ATM	Asynchronous Transfer Mode	Hybrid circuit mode and packet mode	Local Area network backbones	155-622Mbps
FDDI	Fiber Distributed Data Interface	Fiber-Optic data transfer protocol	User install	100Mbps

Table 7. Transmission media in the United States

APPENDIX B: THE TELECOMMUNICATIONS ACT OF 1996

A. INTRODUCTION

Important strides in Federal policy toward health care and the information infrastructure were made in the past year. Before 1996, the Telecommunications Act of 1934 articulated in very general terms a national goal of "universal service;" widespread availability of basic communications services at affordable prices, and did not specifically address health care or telemedicine. The link between health care and universal service policy was made explicit in the Telecommunications Act of 1996 which calls for a revision of the universal service system.

The 1996 Telecommunications Act requires that the Federal Communications Commission (FCC) and the states revise the universal service system based on seven principles, including the principle that schools, libraries, and health care providers should have access to advanced telecommunications services. In addition to these broad principles, additional provisions were made that require the FCC to assure that health care providers serving rural areas have access to telecommunications services "necessary for the delivery of health care" at rates that are comparable to those for similar services in urban areas.

In accordance with the new law, the FCC convened a Joint Board, made up of Federal and state communications commissioners, who will make

recommendations to the FCC in its revision of the overall universal service policy.

The Joint Working Group -Telemedicine, (JWGT) has closely tracked the implementation of this legislation through the FCC and has made its expertise available to the Commission on an individual basis. Several members of the Joint Working Group participated in the Advisory Committee on Telecommunications and Health Care which was convened by the FCC's Chairman to assist both the FCC and the Joint Board in implementing the health care provisions of the Telecommunications Act.

Those such as Associate Administrator Kathryn Brown of the National Telecommunications and Information Administration, Department of Commerce, testified before the FCC on general universal service revisions. More specifically, the chair of the JWGT group, Dena Puskin, Sc.D. testified before the Commission on how the Joint Board should interpret the provisions of the 1996 Communications Act with respect to health care providers and several members of the working group provided Dr. Puskin with important input to her testimony.

In her testimony, Dr. Puskin outlined her recommendations on issues that are "critical for establishing modern telecommunications services to enhance access to badly needed health care services in rural communities." These issues included: the definition of rural areas, the definition of eligible health care providers, the definition of core services, the definition of advanced services and pricing issues. The FCC Advisory Committee adopted Dr. Puskin's definition of

"rural" areas in its recommendations to the Joint Board as well as some of her other recommendations.

The Advisory Committee recommended that "adequate telecommunications infrastructure be made available to rural health care providers. The telecommunication infrastructure must be sufficient to allow eligible healthcare practitioners requesting these services to access a basic set of telemedicine applications necessary for healthcare in rural places. Its recommendation for the basic services to be covered by pricing comparable to that available in urban areas includes:

Internet access (available without long distance charges)

Bandwidth up to 1.544Mbps or equivalent.

Bandwidth up to 4.8 kbps for ambulances.

Moreover, the Advisory Committee recommends that universal support ought to be available both to construct the necessary infrastructure to meet these standards and also make rates in rural areas comparable to rates in urban areas. The level of services that are eligible for this support ought to be reevaluated as technology changes.

On November 7, 1996, the Joint Board presented its recommendations to the FCC regarding universal service. While it made specific recommendations for schools and libraries, the Board decided to postpone its recommendations for health care. The Board requested more detailed information pertaining to health care transmission costs before making a recommendation. These decisions were

publicly released for comment and by May 8, 1997, the FCC had to act on the recommendations of the Joint Board.

Given that the JWGT's individual members had been deeply involved in the development of the Joint Board's recommendations, the JWGT will continue to closely follow and contribute to the Joint Board's deliberation over the next year.

In addition to legal changes, rapid technology advances in telecommunications have and will continue to decrease the costs of transmission over the long term. Technological advances such as data compression allow services such as imaging to be sent over smaller bandwidth at lower costs.

While the FDA allows marketing medical imaging systems that use compression, image compression has not been approved by the American College of Radiology or other standards setting bodies. Therefore, until such time as there is greater consensus on the use of compressed images, the JWGT will continue to base calculations for transmissions rates on uncompressed images.

The current high costs of using the advanced infrastructure can be prohibitive for most rural and some urban healthcare practitioners. Part of the problem lies in the widening gap between those who have access to a modern, reliable information infrastructure and those who do not.

The Telecommunications Act of 1996 seeks to increase access to telehealth providers in rural areas by equalizing the costs of telecommunications services in rural and urban areas. With the help of the JWGT committee and the

efforts of its individual members, over the next year; the JWGT will work with the FCC Joint Board and its Telecommunications Advisory Committee to provide further information about telemedicine infrastructure costs and issues.

The Joint Working Group will also work closely with Federal telemedicine grantees who will provide the FCC with detailed information about their infrastructure costs, what they use the infrastructure for, and the comparative value of different bandwidth for telemedicine purposes.

APPENDIX C: LEVELS OF VIDEOTELECONFERENCING (VTC)

Attributes of IT System	Compact System	Desk-Top System	Group System	Network System
Sys. Function	Mobile Users	Face-to-Face	Simulations distant users	Pre-programmed Video Broadcast
Users Served	Mid-Upper level	All Levels	Upper Level	All levles
IT Level	Simple VTC Low Bandwidth Requirement	Simple Unicast Fit IT-21 - ATM to Desk-Top	Multi-cast, IP, Frame-relay, ATM High bandwidth	Mutli-cast,IP, Switched Networks T.V Quality Viewing
Over all Quality	Low quality Jerky movements		Higher Quality needed to keep participants interest	Best quality, TV level, full length training videos Full motion
Info.processing capability needed	Low resolution 4Hz Telephone Audio	QCIF, Chapt III.C, PCM Audio Appendix A	CIF Chapt III.C PCM Audio Appendix A	Computer digital data either circuit or packet switched Appendix A
Purpose	When a user must be part of a meeting.	Mid-level quality easier way to pass info, Medical consultations	Continuing education courses, distant surgeries, Maintain CME	Real time distance learning CMEs, Remote mechanical surgeries.
Cost	>= $500	$500 to $3000	$1,200 to $10,000	$5,000 to $30,000

APPENDIX D: TELEMEDICAL SYSTEM MANUFACTURERS

Telemedicine systems may be assembled utilizing commercial "off-the-shelf" business teleconferencing equipment and by adapting available medical peripherals, a number of vendors also specialize in specific telemedicine products and value-added services. The following is a list of vendors that have been involved in recent telemedicine projects. This listing is not comprehensive, however, it includes vendors that have been cited in literature active at telemedicine conferences and identified by telemedicine specialists.

Telemedicine System Manufacturers and Integrators

Compression Labs Incorporated (CLI)
Russ Liggett
2860 Junction Avenue San Jose, CA 95134
314-542-3053
Manufacturer of interactive audio/video/data teleconferencing equipment. CLI has teleconferencing equipment available that has been successfully adapted for telemedicine applications. CLI telemedicine systems support multiple medical peripheral inputs.

PictureTel
Stephan Johnson
222 Rosewood Drive Danvers, MA 01923
800-716-6000
Leading manufacturer of business teleconferencing equipment, which has models available that have been successfully adapted for telemedicine applications.

VTEL
Rebecca Whitehead
108 Wild Basid Road Austin, TX 78746
512-314-2660
Manufacturer of interactive audio/video/data teleconferencing equipment, which has models available that have been successfully adapted for telemedicine applications. VTEL also manufactures cameras and other peripheral devices.

Hughes Medical Tele-Imaging
Morgan McCune
P.O. Box 92919 Los Angeles, CA 90009 310-364-6365
(Fax) 310-364-6076
Hughes produces integrated telemedicine systems, as well as networked systems for acquisition and transfer of patient data records and medical images.

DeBakey /Raytheon /ITS
William Stevens 24 Terry Avenue Burlington, MA 01803 617-221-8058
(Fax) 617-221-8110
DeBakey / Raytheon / ITS produces an integrated telemedicine system called Medtel, which is the result of a joint venture of the three medical, technical, and telemedical firms.

ANNEX Media Communications Services
4 West Red Oak Lane White Plains, NY 10606 g 14-644-7971
Medical Televideo Incorporated (MTI) Rod McArthur 2452 Centerline Drive Maryland Heights, MO 63043 MTI is a telemedical systems integrator that specializes in telepathology, telecardiology, and diagnostic instrumentation.

Swiderski Electronics Incorporated
Joseph M. Swiderski III 1200 Greenleaf Avenue Elk Grove Village, IL 60008-5597 708-364-5019
Swiderski is a multidiscipline system integrator and value added reseller that specializes in the design, engineering and installation of a broad range of audio, video, data, and multimedia applications.

United Medical Network
Valeria Oravetz
708 South Third Street, Suite 400
Minneapolis, MN 55415
800-448-6679 612-330-0990 (Fax) 612-330-0989 United Medical Network is a telemedicine services integrator, which also provides dial-up telecommunications infrastructure services specifically for health care applications.

Telemedicine Equipment and Peripheral Providers

Andries Tek
Rondald Williams 4314 Medical Parkway Austin, TX 78756
512-453-6076
(Fax) 512-453-8627
Andries Tek designs, manufactures or supplies a comprehensive variety of medical peripheral equipment (i.e., electronic stethoscopes, skin cameras, dopplers, endoscopic camera adapters, etc.), which is compatible with many of the leading manufacturers' teleconferencing and telemedicine systems.

Video Dynamics Incorporated (VDI)
Wayne Byard 13790 NW 4th Street Suite 112 Sunrise, FL 33325
305-846-1490
(Fax) 305-846-1949
VDI manufactures a wide variety of medical peripheral equipment including micro-soakable cameras, ENT equipment, light sources, as well as other telemedical peripheral equipment.

Elmo Manufacturing Company 70 New Hyde Park Road New Hyde Park, NY 11040 516-775-3200
Elmo manufactures a widely used desktop visual presenter for displaying documents, lowresolution radiographs, and objects.

Canon USA
One Cannon Plaza
Lake Success, NY 11042
516-328-5960
(Fax) 516-328-5959
Cannon manufactures still video cameras, video visualizers, and PC-based image digitizers, which may be adapted for use in telemedicine systems.

AMX Corporation
11995 Foretgate Drive Dallas, TX 75243
800-222-0193 214-644-3048
(Fax) 214-907-2053
AMX manufactures icon driven touch screen controllers that have been optimized for telemedicine applications.

Heraeus Surgical Incorporated
575 Cottonwood Drive Milpitas, CA 95035
408-954-4000
(Fax) 408-954-4040
Heraeus markets interactive surgical video systems that provide an integrated video network for use in monitoring, consulting, teaching, teleconferencing, and documenting of surgical procedures and surgical pathology.

Stryker Endoscopy
Frances Roche 2
10 Baypointe Parkway San Jose, CA 95134
408-435-0220
(Fax) 408-435-1888
Stryker manufactures integrated endoscopic surgical suites that centralize control of all video functions within a surgical suite.

Corabi Limited
Mark Neuberger 890 South Pickett Street Alexandria, VA 22304
703-823-4753
(Fax) 703-823-2584) Corabi manufactures telerobotic pathology workstations that allow remote visualization and manipulation of laboratory microscopes and peripheral equipment.

AT&T
Lisa Grote
15 West 6th Street, 3rd Floor
Cincinnati, OH 45202
800-245-0266 Extension 5911
(Fax) 800-289-0026
AT&T still-image picture phones can send still images over ordinary analog phone lines. Image sources may be camcorders, document scanners, photo CDs, as well as a host of other devices.

ScoffCare
Mary Hall I I S B West Ticonderoga Westville, OH 43081
800-308-3148 216-362-0550
(Fax) 362-6162
ScottCare has developed an integrated medical telemetry system for cardiac rehabilitation applications, which may be used by patients at remote locations under the supervision of a nurse at a central location.

In Vision Systems Incorporated
Dave Gersh
703-506-0094
(Fax) 703-506-0098
InVision is a leading developer of protocol-independent desktop conferencing systems.

APPENDIX E: TELECOMMUNICATION GLOSSARY

Access Line
A communications line (e.g. circuit) interconnecting a frame-relay-compatible device (DTE) to a frame-relay switch (DCE). See also Trunk Line.

Access Rate (AR)
The data rate of the user access channel. The speed of the access channel determines how rapidly (maximum rate) the end user can inject data into a frame relay network.

American National Standards Institute (ANSI)
Devises and proposes recommendations for international communications standards. See also Comite Consultatif International Telegraphique et Telephonique (CCITT).

Backward Explicit Congestion Notification (BECN)
A bit set by a frame relay network to notify an interface device (DTE) that congestion avoidance procedures should be initiated by the sending device.

Bandwidth
The range of frequencies, expressed in Kilobits per second, that can pass over a given data transmission channel within a frame relay network. The bandwidth determines the rate at which information can be sent through a channel - the greater the bandwidth, the more information that can be sent in a given amount of time.

Bridge
A device that supports LAN-to-LAN communications. Bridges may be equipped to provide frame relay support to the LAN devices they serve. A frame-relay-capable bridge encapsulates LAN frames in frame relay frames and feeds those frame relay frames to a frame relay switch for transmission across the network. A frame-relay-capable bridge also receives frame relay frames from the network, strips the frame relay frame off each LAN frame, and passes the LAN frame on to the end device. Bridges are generally used to connect local area network (LAN) segments to other LAN segments or to a wide area network (WAN). They route traffic on the Level 2 LAN protocol (e.g., the Media Access Control address), which occupies the lower sub layer of the LAN OSI data link layer. See also Router.

Burstiness
In the context of a frame relay network, data that uses bandwidth only sporadically; that is, information that does not use the total bandwidth of a circuit 100 percent of the time. During pauses, channels are idle; and no traffic flows across them in either direction. Interactive and LAN-to-LAN data is bursty in nature, because it is sent intermittently, and in between data transmissions the channel experiences idle time waiting for the DTEs to respond to the transmitted data user's input of waiting for the user to send more data.

Channel
Generically refers to the user access channel across which frame relay data travels. Within a given T1 or E1 physical line, a channel can be one of the following, depending of how the line is configured.

Unchannelized
The entire T1/E1 line is considered a channel, where:
The T1 line operates at speeds of 1.536 Mbps and is a single channel consisting of 24 T1 time slots.
The E1 line operates at speeds of 1.984 Mbps and is a single channel consisting of 20 E1 time slots.

Channelized
The channel is any one of N time slots within a given line, where:
The T1 line consists of any one or more channels. Each channel is any one of 24 time slots. The T1 line operates at speeds in multiples of 56/64 Kbps to 1.536 Mbps, with aggregate speed not exceeding 1.536 Mbps.
The E1 line consists of one or more channels. Each channel is any one of 31 time slots. The E1 line operates at speeds in multiples of 64 Kbps to 1.984 Mbps, with aggregate speed not exceeding 1.984 Mbps.
Fractional The T1/E1 channel is one of the following groupings of consecutively or nonconsecutively assigned time slots:
N T/1 time slots (NX56/64Kbps where N = 1 to 23 T1 time slots per FT1 channel). N E1 time slots (NX64Kbps, where N = 1 to 30 time slots per E1 channel).

Channel Service Unit (CSU)
An ancillary device needed to adapt the V.35 interface on a F.R. DTE to the T1 (or E1) interface on a frame relay switch. The T1 (or E1) signal format on the frame relay switch is not compatible with the V.35 interface on the DTE: therefore, a CSU or similar device, placed between the DTE and the frame relay switch, is needed to perform the required conversion.

Committed Burst Size (Bc)
The maximum amount of data (in bits) that the network agrees to transfer, under normal conditions, during a time interval Tc. See also Excess Burst Size (Be).

Comite Consultatif International Telegraphique et Telephonique (CCITT)
International Consultative Committee for Telegraphy and Telephony, a standards organization that devises and proposes recommendations for international communications. See also American National Standards Institute (ANSI).

Committed Information Rate (CIR)
The committed rate (in bits per second) at which the ingress access interface trunk interfaces, and egress access interface of a frame relay network transfer information to the destination frame relay end system under normal conditions. The rate is averaged over a minimum time interval Tc.

Committed Rate Measurement Interval (Tc)
The time interval during which the user can send only Bc-committed amount of data and Be excess amount of data. In general, the duration of Tc is proportional to the "burstiness" of the traffic. Tc is computed (from the subscription parameters of CIR and Bc) as Tc = Bc/CIR. Tc is not a periodic time interval. Instead, it is used only to measure incoming data, during which it acts like a sliding window. Incoming data triggers the Tc interval, which continues until it completes its commuted duration. See also Committed Information Rate (CIR) and committed Burst Size (Bc).

Cyclic Redundancy Check (CRC)
A computational means to ensure the accuracy of frames transmitted between devices in a frame relay network. The mathematical function is computed, before the frame is transmitted, at the originating device. Its numerical value is computed based on the content of the frame. This value is compared with a recomputed value of the function at the destination device. See also Frame Check Sequence (FCS).

Data Communications Equipment (DCE)
Term defined by both frame relay and X.25 committees, that applies to switching equipment and is distinguished from the devices that attach to the network (DTE). Also see DTE.

Data Link Connection Identifier (DLCI)
A unique number assigned to a PVC end point in a frame relay network. Identifies a particular PVC endpoint within a user's access channel in a frame relay network and has local significance only to that channel.

Discard Eligibility (DE)

A user-set bit indicating that a frame may be discarded in preference to other frames if congestion occurs, to maintain the committed quality of service within the network. Frames with the DE bit set are considered Be excess data. See also Excess burst Size (Be).

Egress
Frame relay frames leaving a frame relay network in the direction toward the destination device. Contrast with Ingress.

End Device
The ultimate source or destination of data flowing through a frame relay network sometime referred to as a Data Terminal Equipment (DTE). As a source device, it sends data to an interface device for encapsulation in a frame relay frame. As a destination device, it receives de-encapsulated data (i.e., the frame relay frame is stripped off, leaving only the user's data) from the interface device. Also see DCE
NOTE: An end device can be an application program or some operator-controlled device (e.g., workstation). In a LAN environment, the end device could be a file server or host.

Encapsulation
A process by which an interface device places an end device's protocol-specific frames inside a frame relay frame. The network accepts only frames formatted specifically for frame relay; hence, interface devices acting as interfaces to an frame relay network must perform encapsulation. See also Interface device or Frame-Relay-Capable Interface Device.

Excess Burst Size (Be)
The maximum amount of uncommitted data (in bits) in excess of Bc that a frame relay network can attempt to deliver during a time interval Tc. This data (Be) generally is delivered with a lower probability than Bc. The network treats Be data as discard eligible. See also Committed burst Size (Bc).

E1
Transmission rate of 2.048 Mbps on E1 communications lines. An E1 facility carriers a 2.048 Mbps digital signal. See also T1 and channel.

File Server
In the context of frame relay network supporting LAN-to-LAN communications, a device connecting a series of workstations within a given LAN. The device performs error recover and flow control functions as well as end-to-end acknowledgment of data during data transfer, thereby significantly reducing overhead within the frame relay network.

Forward Explicit Congestion Notification (FECN)
A bit set by a frame relay network to notify an interface device (DTE) that congestion avoidance procedures should be initiated by the receiving device. See also BECN.

Frame Check Sequence (FCS)
The standard 16-bit cyclic redundancy check used for HDLC and frame relay frames. The FCS detects bit errors occurring in the bits of the frame between the opening flag and the FCS, and is only effective in detecting errors in frames no larger than 4096 octets. See also Cyclic Redundancy Check (CRC).

Frame-Relay-Capable Interface Device
A communications device that performs encapsulation. Frame-relay-capable routers and bridges are examples of interface devices used to interface the customer's equipment to a frame relay network. See also Interface Device and Encapsulation.

Frame Relay Frame
A variable-length unit of data, in frame-relay format that is transmitted through a frame relay network as pure data. Contrast with Packet. See also Q.922A.

Frame Relay Network
A telecommunications network based on frame relay technology. Data is multiplexed. Contrast with Packet-Switching Network.

High Level Data Link control (HDLC)
A generic link-level communications protocol developed by the International Organization for Standardization (ISO). HDLC manages synchronous, code-transparent, serial information transfer over a link connection. See also Synchronous Data Link Control (SDLC).

Hop
A single trunk line between two switches in a frame relay network. An established PVC consists of a certain number of hops, spanning the distance from the ingress access interface to the egress access interface within the network.

Host Computer
A communications device that enables users to run applications programs to perform such functions as text editing, program execution, access to data bases, etc.

Ingress
Frame relay frames from an access device toward the frame relay network. Contrast with Egress.

Interface Device
Provides the interface between the end device(s) and a frame relay network by encapsulating the user's native protocol in frame relay frames and sending the frames across the frame relay backbone. See also Encapsulation and Frame-Relay-Capable Interface Device.

Link Access Procedure Balanced (LAPB)
The balanced-mode, enhanced, version of HDLC. Used in X.25 packet-switching networks. Contrast with LAPD.

Link Access Procedure on the D-channel (LAPD)
A protocol that operates at the data link layer (layer 2) of the OSI architecture. LAPD is used to convey information between layer 3 entities across the frame relay network. The D-channel carries signaling information for circuit switching. Contrast with LAPB.

Local Area Network (LAN)
A privately owned network that offers high-speed communications channels to connect information processing equipment in a limited geographic area.

LAN Protocols
A range of LAN protocols supported by a frame relay network, including Transmission Control Protocol/Internet Protocol (TCP/IP), Apple Talk, Xerox Network System (XNS), Internetwork Packet Exchange (IPX), and Common Operating System used by DOS-based PCs.

LAN Segment
In the context of a frame relay network supporting LAN-to-LAN communications, a LAN linked to another LAN by a bridge. Bridges enable two LANs to function like a single, large LAN by passing data from one LAN segment to another. To communicate with each other, the bridged LAN segments must use the same native protocol. See also Bridge.

Packet
A group of fixed-length binary digits, including the data and call control signals, that are transmitted through an X.25 packet-switching network as a composite whole. The data, call control signals, and possible error control information are arranged in a predetermined format. Packets do not always travel the same pathway but are arranged in proper sequence at the destination side before forwarding the complete message to an addressee. Contrast with Frame Relay Frame.

Packet-Switching Network
A telecommunications network based on packet-switching technology, wherein a transmission channel is occupied only for the duration of the transmission of the packet. Contrast with Frame Relay Network.

Parameter
A numerical code that controls an aspect of terminal and/or network operation. Parameters control such aspects as page size, data transmission speed, and timing options.

Permanent virtual Circuit (PVC)
A frame relay logical link, whose endpoints and class of service are defined by network management. Analogous to an X.25 permanent virtual circuit, a PVC (often referred to as a PVC) consists of the originating frame relay network element address, originating data link control identifier, terminating frame relay network element address, and termination data link control identifier. Originating refers to the access interface from which the PVC is initiated. Terminating refers to the access interface at which the PVC stops. Many data network customers require a PVC between two points. Data terminating equipment with a need for continuous communication use PVCs. See also Data Link Connection Identifier (DLCI).

Q.922 Annex A (Q.922A)
The international draft standard that defines the structure of frame relay frames. Based on the Q.922A frame format developed by the CCITT. All frame relay frames entering a frame relay network automatically conform to this structure. Contrast with Link Access Procedure Balanced (LAPB).

Q.922A Frame
A variable-length unit of data, formatted in frame-relay (Q.922A) format, that is transmitted through a frame relay network as pure data (i.e., it contains no flow control information). Contrast with Packet. See also Frame Relay Frame.

Router
A device that supports LAN-to-LAN communications. Routers may be equipped to provide frame relay support to the LAN devices they serve. A frame-relay-capable router encapsulates LAN frames in frame relay frames and feeds those frame relay frames to a frame relay switch for transmission across the network. A frame-relay-capable router also receives frame relay frames from the network, strips the frame relay frame off each frame to product the original LAN frame, and passes the LAN frame on to the end device. Routers connect multiple LAN segments to each other or to a WAN. Routers route traffic on the Level 3 LAN protocol (e.g., the Internet Protocol address). See also Bridge.

Statistical Multiplexing
Interleaving the data input of two or more devices on a single channel or access line for transmission through a frame relay network. Interleaving of data is accomplished using the DLCI.

Synchronous Data Link Control (SDLC)
A link-level communications protocol used in an International Business Machines (IBM) Systems Network Architecture (SNA) network that manages synchronous, code-transparent, serial information transfer over a link connection. SDLC is a subset of the more generic High-Level Data Link Control (HDLC) protocol developed by the International Organization for Standardization (ISO).

T1
Transmission rate of 1.544 Mbps on T1 communications lines. A T1 facility carriers a 1.544 Mbps digital signal. Also referred to as digital signal level 1 (DS-1). See also E1 and channel.

Trunk Line
A communications line connecting two-frame relay switches to each other.

APPENDIX F: TELEMEDICAL PERIPHERAL INPUT DEVICES

General Purpose Devices	Price Ranges
Plain-paper fax machine	$350- $1,500
Flat-bed page scanner	150- 5,000
Radiographic film scanner	18,000- 75,000
Digital Frame Grabber	180- 3,000
Video Visualizer / Presenter	5,000- 7,000
Digitizing Graphics Tablet	1,000- 8,000
CCD Camera	3,000- 15,000
Camera and Adapters for:	
Otoscopes	1,500- 10,000
Ophthalmoscopes	3,500- 10,000
Flexible Endoscopes	4,500- 10,000
Electronic Stethoscopes	2,500- 8,000
Hand-Held Still-Image Camera	300- 10,000
Specialty Devices	
ECG machine with modem or communications ports	4,000- 14,000
ECG and EEG transmission devices	500- 5,000
Pathology microscope camera	4,000- 8,000
Remote-controlled pathology microscope system	65,000 -110,000
Dermatology skin camera (Dermascope)	2,500- 10,000

As stated by Moores' Law, prices will vary widely depending on features, specifications, options, and their age in the technology cycle. By the time you read this information, the above prices will most likely have decreased. This only proves that Mr. Gordon Moore's (Intel co-founder) 1965 prediction that the computer technology is on a 18 month cycle is still valid.

LIST OF REFERENCES

1. A.D. Little, Inc., *Telecommunications: Can it Help Solve America's Health Care Problems?* Arthur D. Little, Incorporated, Acorn Park, Cambridge, Massachusetts, Reference 91810-98, July 1992.

2. Allen, A., "American Telemedicine in the 1990's, *"Telemedicine Today,* 3(2), pp. 1-5 February 2, 1995.

3. Bashshur, R.L., ed., *Telemedicine: Explorations in the Use of Telecommunications in Health Care,* Springfield, IL: Thomas, 1975.

4. Bashshur, R.L., "Telemedicine Effects: Cost, Quality and Access," Position paper for presentation and discussion at the Second National Aeronautics and Space Administration/Uniformed Services University of the Health Sciences International.

5. Berek, B., and Canna, M., "Telemedicine on the Move: Health Care Heads Down the Information Superhighway," *American Hospital Association, Hospital Technology Series (ISSN0888-711X),* 11(4),pp. 1-65,April 1994.

6. Freeman, M., "Telecommunications Transmission Handbook"1991, ISDN0-471-51816-6.

7. Global Telemedicine Report, July 1994, p.14.

8. HIMSS, Poster Session number 27, Annual Conference 1996.

9. Mary Moore, Ph.D, "Telemedicine Cost Justification", University of Texas, February 2, 1996, Department of Business.

10. McGee, R., and Tangalos, E., "Delivery of Health Care to the Underserved: Potential Contributions of Telecommunications Technology," Mayo Clinic Proceedings, *69:* pp. *113* 1-1 *136, 1994.*

11. Murphy, R. and Bird, K., "Telediagnosis: A New Community Health Resource: Observations on the Feasibility of Telediagnosis Based on 1000 Patient Transactions," *American Journal of Public Health, 64:* pp. 113-119, June *1974.*

12. NIST (National Institutes of Standards and Technology), *Putting the Information Infrastructure to Work: Report of the Information Infrastructure Task Force Committee on Applications and Technology, U.S.* Department of Commerce, pp. *41-56,* May 3, *1994.*

13. NMIMC (Naval Medical Information Management Center), Secretary of Defense Point Paper: Navy Telemedicine Initiative, *1994.*

14. PictureTel Corporation, "Videoconferencing Technology Primer," pp. 1-3, *1993.*

15. Preston, J., *The Telemedicine Handbook,* Telemedical Interactive Consultative Services, Incorporated, Austin, TX, *1993.*

16. Sanders, Telemedicine Journal, 1, 2, Summer 1995.

17. SCI Systems of Houston, Texas study, "Resolution and Technology Trade off, " Aug. 1997.

18. Southeast Medical Network Implementation Plan, June 1997.

19. Telecommunications Transmission Engineering, Vol. 1 AT&T Co., 1974.

20. www.whitehouse.gov/wh/eop/ovp/html/nii1.html, Vice President Al Gore National Information Infrastructure

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